US009386593B2

(12) **United States Patent**
Park et al.

(10) **Patent No.: US 9,386,593 B2**
(45) **Date of Patent: Jul. 5, 2016**

(54) **SYSTEMS AND METHODS FOR COMPONENT CARRIER SELECTION IN A WIRELESS COMMUNICATION SYSTEM**

(75) Inventors: **Kenneth James Park**, Cathlament, WA (US); **Ahmad Khoshnevis**, Portland, OR (US); **Kimihiko Imamura**, Vancouver, WA (US); **John M. Kowalski**, Camas, WA (US); **Sayantan Choudhury**, Vancouver, WA (US)

(73) Assignee: **Sharp Kabushiki Kaisha**, Osaka (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **12/488,478**

(22) Filed: **Jun. 19, 2009**

(65) **Prior Publication Data**

US 2010/0322185 A1 Dec. 23, 2010

(51) **Int. Cl.**
H04W 72/04 (2009.01)
H04W 72/08 (2009.01)

(52) **U.S. Cl.**
CPC ***H04W 72/085*** (2013.01); *H04W 72/0453* (2013.01)

(58) **Field of Classification Search**
CPC H04W 72/04; H04W 88/08; H04W 76/00
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,285,447	A *	2/1994	Hulsebosch	370/332
5,691,974	A *	11/1997	Zehavi et al.	370/203
7,966,017	B2 *	6/2011	Kim et al.	455/436
8,559,992	B2 *	10/2013	Larsson et al.	455/501
2004/0028015	A1 *	2/2004	Fouilland et al.	370/337
2005/0075125	A1 *	4/2005	Bada et al.	455/525
2005/0124344	A1 *	6/2005	Laroia et al.	455/436
2005/0180364	A1 *	8/2005	Nagarajan et al.	370/335
2005/0271012	A1 *	12/2005	Agrawal et al.	370/331
2006/0153283	A1 *	7/2006	Scharf et al.	375/148
2007/0177501	A1 *	8/2007	Papasakellariou	370/229
2007/0195734	A1 *	8/2007	Das et al.	370/335
2008/0227456	A1 *	9/2008	Huang et al.	455/436
2008/0240439	A1 *	10/2008	Mukherjee et al.	380/272
2008/0259876	A1 *	10/2008	Qiang et al.	370/332

(Continued)

FOREIGN PATENT DOCUMENTS

CN	101203034 A	6/2008
WO	2010/125769	11/2010

OTHER PUBLICATIONS

Teyeb et al, Dynamic Relaying in 3GPP LTE-Advanced Networks, Jan. 2009, EURASIP Journal on Wireless Communication and Networking, vol. 2009, see entire document, pp. 1-10.*

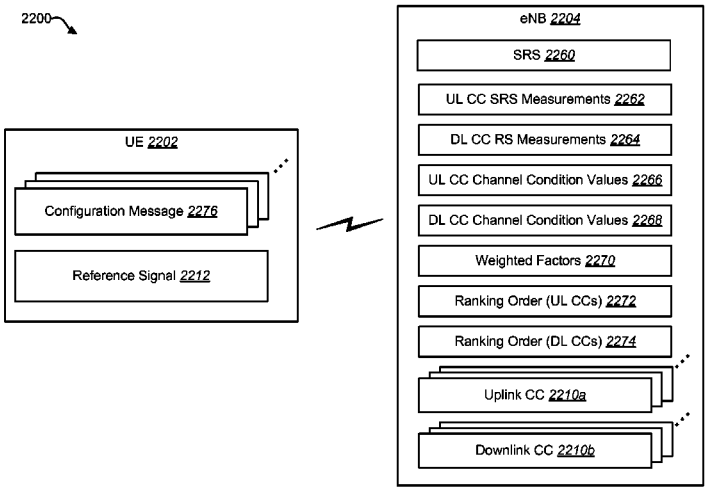
(Continued)

Primary Examiner — Hassan Phillips
Assistant Examiner — Prenell Jones
(74) *Attorney, Agent, or Firm* — Austin Rapp & Hardman

(57) **ABSTRACT**

The present disclosure relates to component carrier (CC) selection in a wireless communication system. A user equipment (UE) that is in idle mode may receive a reference signal (RS) from an evolved Node B (eNB), obtain signal quality measurements with respect to the RS, and switch to a new CC based on the signal quality measurements. For a UE that is in connected mode, an eNB may obtain uplink channel condition information corresponding to uplink CCs, obtain downlink channel condition information corresponding to downlink CCs, and select a CC pair for the UE to use based on the uplink channel condition information and the downlink channel condition information.

7 Claims, 28 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2008/0267131	A1	10/2008	Kangude et al.	
2009/0046625	A1*	2/2009	Diener et al.	370/319
2009/0046656	A1*	2/2009	Kitazoe et al.	370/331
2009/0046665	A1*	2/2009	Robson et al.	370/332
2009/0088164	A1*	4/2009	Shen et al.	455/436
2009/0124261	A1*	5/2009	Shimomura	455/436
2009/0129336	A1*	5/2009	Osborn	370/331
2009/0154588	A1*	6/2009	Chen et al.	375/267
2009/0161527	A1*	6/2009	Yu	370/203
2009/0180435	A1*	7/2009	Sarkar	370/330
2009/0264077	A1*	10/2009	Damnjanovic	455/63.1
2009/0279480	A1*	11/2009	Rosenqvist et al.	370/328
2009/0285158	A1*	11/2009	Rezaiifar et al.	370/328
2009/0296595	A1*	12/2009	Khoshnevis et al.	370/252
2009/0316676	A1*	12/2009	Kolding et al.	370/345
2010/0039948	A1*	2/2010	Agrawal et al.	370/252
2010/0039950	A1*	2/2010	Kazmi	370/252
2010/0054207	A1*	3/2010	Gupta et al.	370/331
2010/0080187	A1*	4/2010	Papasakellariou et al.	370/329
2010/0118992	A1*	5/2010	Terabe	375/260
2010/0227614	A1*	9/2010	Chun et al.	455/436
2010/0303039	A1*	12/2010	Zhang et al.	370/331
2011/0013506	A1*	1/2011	Ishii et al.	370/208
2011/0086639	A1*	4/2011	Kalervo Hamalainen et al.	455/436
2011/0090879	A1*	4/2011	Hamiti et al.	370/338
2011/0096713	A1*	4/2011	Rusert et al.	370/312
2011/0117916	A1*	5/2011	Dahlen	455/436
2011/0149913	A1*	6/2011	Park et al.	370/332
2011/0275374	A1*	11/2011	Narasimha et al.	455/436
2011/0286433	A1*	11/2011	Xiao et al.	370/331
2012/0026976	A1*	2/2012	Chang et al.	370/331
2012/0063417	A1*	3/2012	Redana et al.	370/331
2012/0083199	A1*	4/2012	Redana et al.	455/7
2012/0108283	A1*	5/2012	Pedersen et al.	455/509
2014/0016602	A1*	1/2014	Papasakellariou et al.	370/329

OTHER PUBLICATIONS

Nokia Siemens Networks, Nokia, "Use of Background Interference Matrix for Autonomous Component Carrier Selection for LTE-Advanced," R1-090736, Feb. 2009.

International Search Report issued for International Patent Application No. PCT/JP2010/057523 on Aug. 10, 2010.

3GPP TS 36.300 V8.1.0, "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description," Jun. 2007.

3GPP TS 36.331 V8.5.0, "Evolved Universal Terrestrial Radio Access (E-UTRA) Radio Resource Control (RRC); Protocol specification," Mar. 2009.

3GPP TS 36.321 V8.5.0, "Evolved Universal Terrestrial Radio Access (E-UTRA) Medium Access Control (MAC); Protocol specification," Mar. 2009.

3GPP TS 36.814 V0.4.1, "Further Advancements for E-UTRA; Physical Layer Aspects," Feb. 2009.

3GPP TS 36.214 V8.6.0, "Evolved Universal Terrestrial Radio Access (E-UTRA) Physical layer—Measurements," Mar. 2009.

3GPP TS 36.213 V8.6.0, "Evolved Universal Terrestrial Radio Access (E-UTRA) Physical layer procedures," Mar. 2009.

3GPP TS 36.212 V8.6.0, "Evolved Universal Terrestrial Radio Access (E-UTRA) Multiplexing and channel coding," Mar. 2009.

3GPP TS 36.211 V8.6.0, "Evolved Universal Terrestrial Radio Access (E-UTRA) Physical Channels and Modulation," Mar. 2009.

Huawei, "RAN2 Considerations for Carrier Aggregation," R2-092180, Mar. 2009.

Motorola, "MAC-Layer Impacts of Bandwidth Aggregation," R2-092357, Mar. 2009.

CMCC, "Discussions on Carrier Aggregation in RAN2," R2-092411, Mar. 2009.

Catt, "Considerations on Carrier Aggregation in RAN2," R2-092991, May 2009.

Ericsson, "Control Plane Aspects of Carrier Aggregation," R2-092958, May 2009.

Ericsson, "Impact of Carrier Aggregation on the L2 Protocol Architecture for LTE Rel-10," R2-092957, May 2009.

Huawei, "Carrier Aggregation in Active Mode," R2-093104, May 2009.

Huawei, "Measurement Report Triggering Asynchronization in CA," R2-093108, May 2009.

Motorola, "Layer-2 Structure for LTE-A Carrier Aggregation," R2-093204, May 2009.

NEC, "Higher Layer Functions to Support Carrier Aggregation," R2-093287, May 2009.

Nokia Siemens Networks, Nokia Corporation, "Idle Mode Mobility in Carrier Aggregation Scenarios," R2-093229, May 2009.

Panasonic, "Synchronization Channel and System Information for Carrier Aggregation," R2-092866, May 2009.

LG Electronics, "Proposals and Issues on the Carrier Aggregation and Control Signaling for LTE-A," R1-084194, Nov. 2008.

LG Electronics, "Considerations on DL/UL Transmission in Asymmetric Carrier Aggregation," R1-084197, Nov. 2008.

CATT, RITT, "Carrier Aggregation for LTE-A," R1-084288, Nov. 2008.

CMCC, "Key Issues in Carrier Aggregation," R1-084332, Nov. 2008.

Huawei, "Carrier Aggregation in LTE-Advanced," R1-084346, Nov. 2008.

Ericsson, "Carrier Aggregation," R1-084374, Nov. 2008.

Qualcomm Europe, "Carrier Aggregation Operation in LTE-Advanced," R1-084397, Nov. 2008.

Texas Instruments, "Issues on Carrier Aggregation for Advanced E-UTRA," R1-084443, Nov. 2008.

Nokia Siemens Networks, Nokia, "Algorithms and Results for Autonomous Component Carrier Selection for LTE-Advanced," R1-084321, Nov. 2008.

Samsung, "Initial Random Access in Asymmetric Carrier Aggregation," R1-090093, Jan. 2009.

CATT, RITT, "Carrier Aggregation for LTE-A," R1-090187, Jan. 2009.

Texas Instruments, "RACH Procedure for Asymmetric Carrier Aggregation," R1-090284, Jan. 2009.

Ericsson, "Control Signaling for Carrier Aggregation," R1-090375, Jan. 2009.

Nortel, "Initial Random Access for Asymmetric Carrier Aggregation," R1-090762, Feb. 2009.

LG Electronics, "Considerations on DL/UL Transmission in Asymmetric Carrier Aggregation," R1-090781, Feb. 2009.

Motorola, "Control Signaling Design for Supporting Carrier Aggregation," R1-090792, Feb. 2009.

Huawei, "Consideration on Carrier Aggregation for Home eNB," R1-090817, Feb. 2009.

Nokia Siemens Networks, Nokia, "Primary Component Carrier Selection, Monitoring, and Recovery," R1-090735, Feb. 2009.

Samsung, "Initial Random Access in Asymmetric Carrier Aggregation," R1-091241, Mar. 2009.

Texas Instruments, "On RACH Procedure for Asymmetric Carrier Aggregation," R1-091298, Mar. 2009.

Motorola, "Initial Random Access Procedure for Asymmetric Carrier Aggregation," R1-091328, Mar. 2009.

Nortel, "Initial Random Access for Asymmetric Carrier Aggregation," R1-091398, Mar. 2009.

3GPP TS 36.304 V8.5.0, "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) Procedures in Idle Mode," Mar. 2009.

Decision to Grant a Patent issued for Japanese Patent Application No. JP 2011-550341 on May 8, 2012.

Huawei, "Carrier Aggregation in Advanced E-UTRA", R1-082448, Jun. 30, 2008.

* cited by examiner

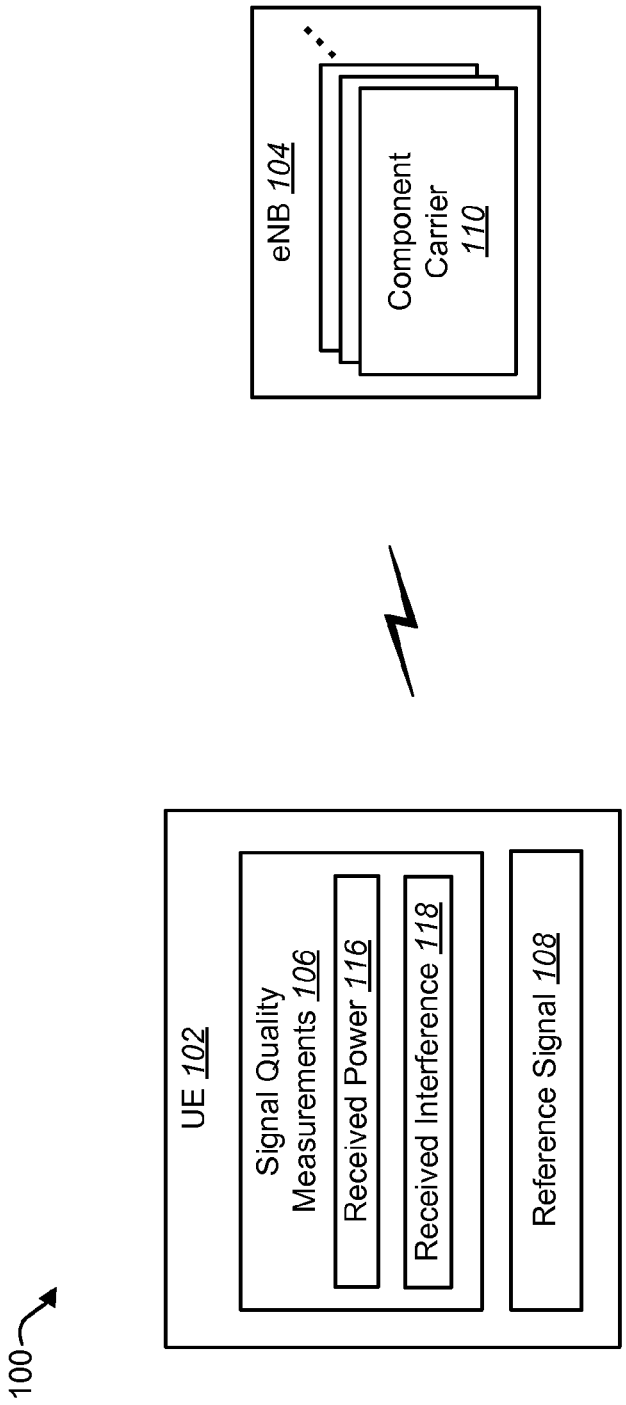

100
UE 102
Signal Quality Measurements 106
Received Power 116
Received Interference 118
Reference Signal 108
eNB 104
Component Carrier 110

FIG. 1

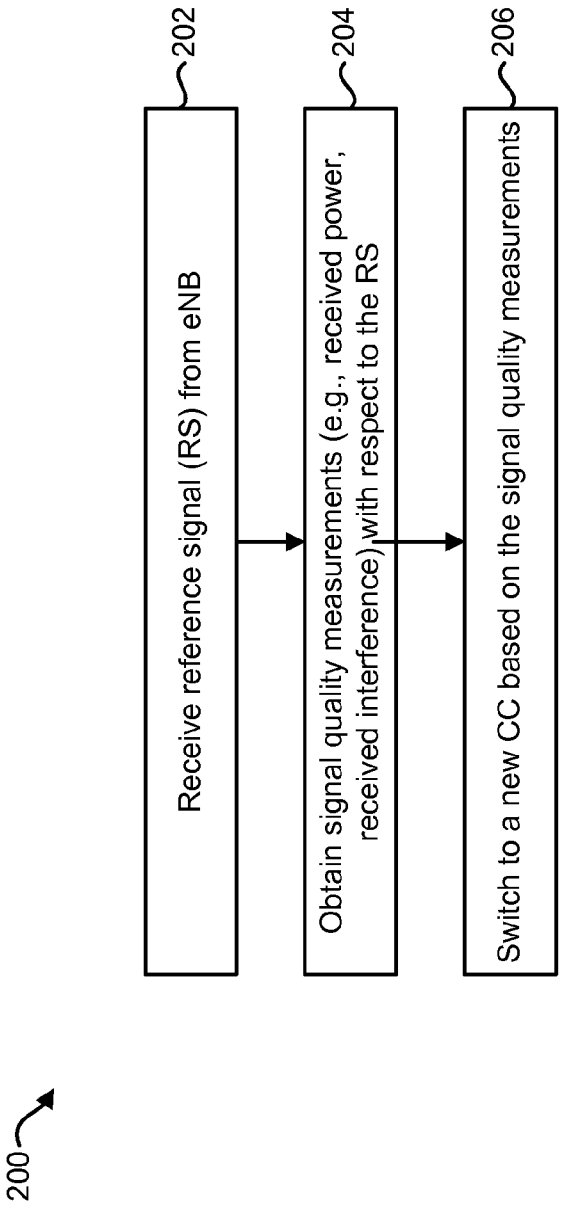

200
202
Receive reference signal (RS) from eNB
204
Obtain signal quality measurements (e.g., received power, received interference) with respect to the RS
206
Switch to a new CC based on the signal quality measurements

FIG. 2

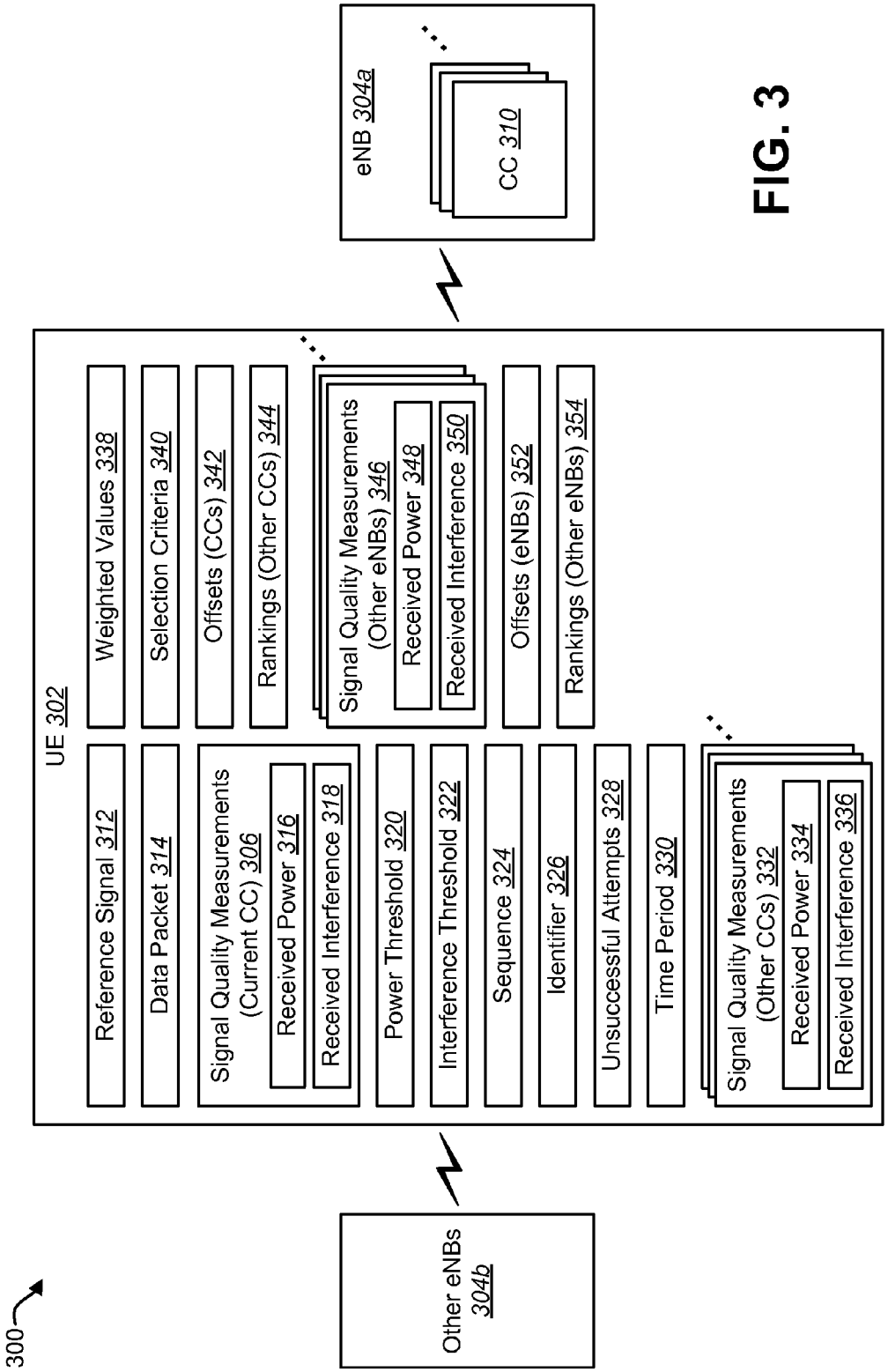

300
Other eNBs 304b
UE 302
Reference Signal 312
Data Packet 314
Signal Quality Measurements (Current CC) 306
Received Power 316
Received Interference 318
Power Threshold 320
Interference Threshold 322
Sequence 324
Identifier 326
Unsuccessful Attempts 328
Time Period 330
Signal Quality Measurements (Other CCs) 332
Received Power 334
Received Interference 336
Weighted Values 338
Selection Criteria 340
Offsets (CCs) 342
Rankings (Other CCs) 344
Signal Quality Measurements (Other eNBs) 346
Received Power 348
Received Interference 350
Offsets (eNBs) 352
Rankings (Other eNBs) 354
eNB 304a
CC 310

FIG. 3

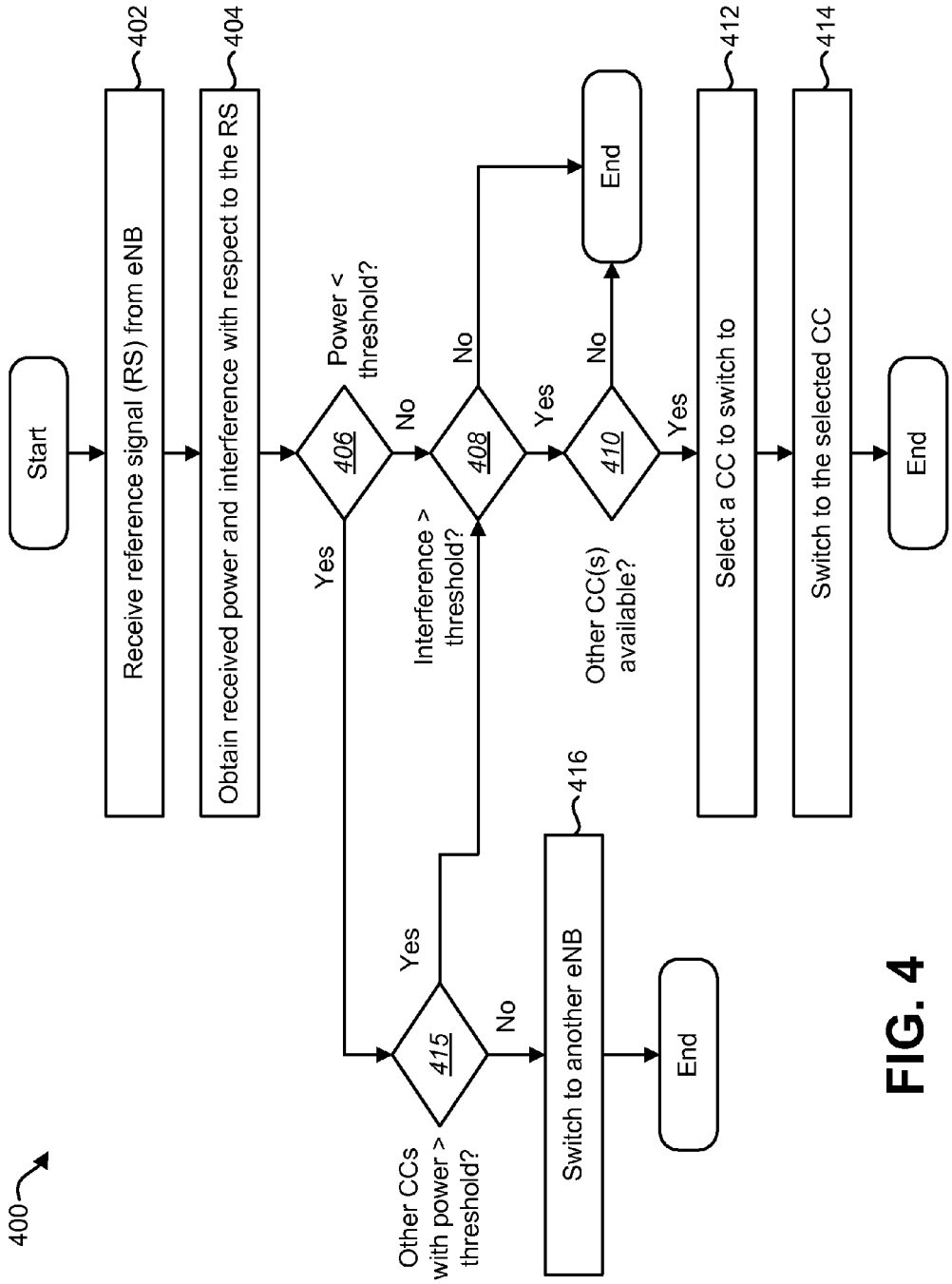

400
Start
Receive reference signal (RS) from eNB
402
Obtain received power and interference with respect to the RS
404
406
Power < threshold?
Yes
No
408
Interference > threshold?
Yes
No
410
Other CC(s) available?
Yes
No
End
Select a CC to switch to
412
Switch to the selected CC
414
End
415
Other CCs with power > threshold?
Yes
No
416
Switch to another eNB
End

FIG. 4

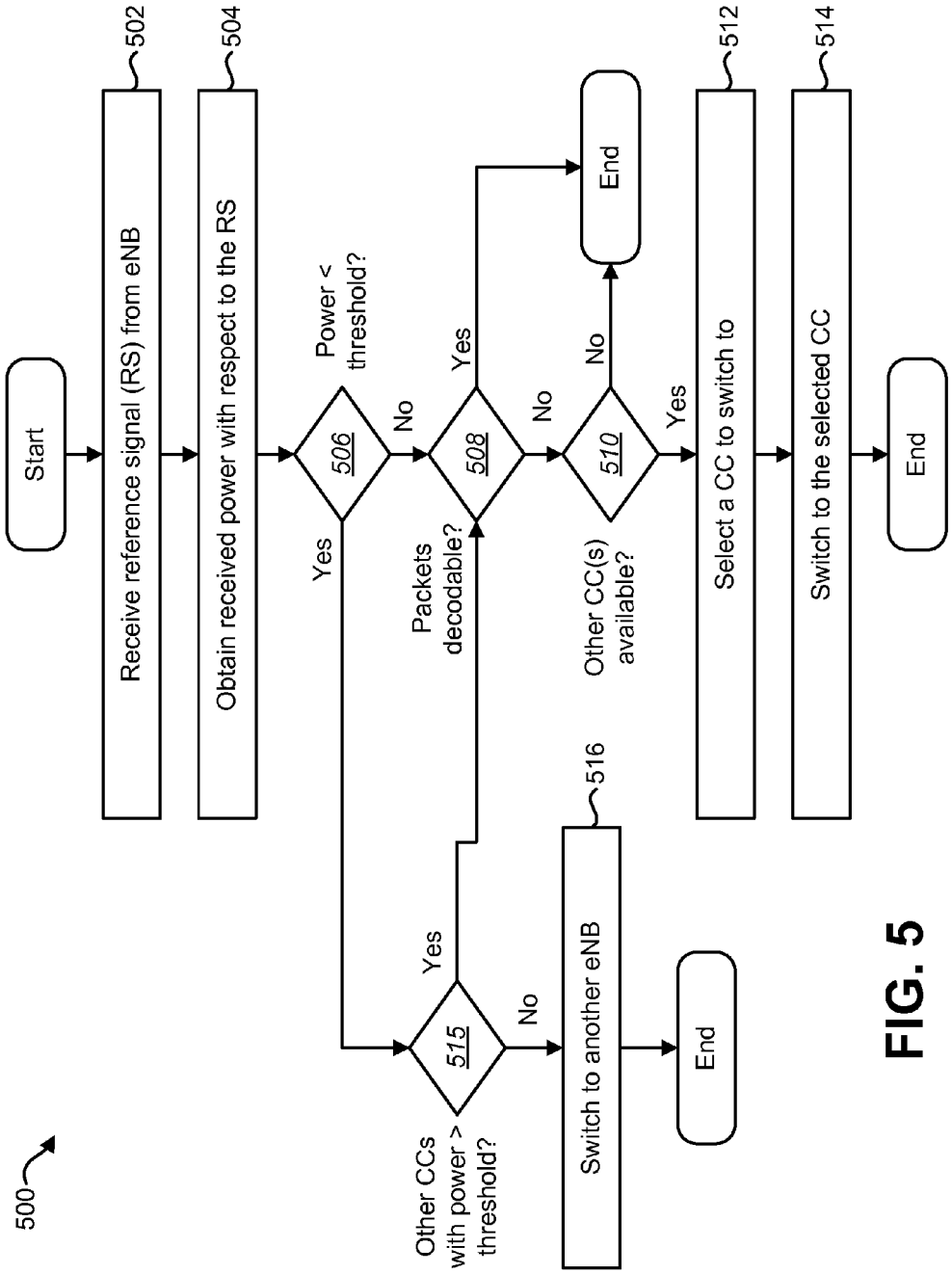

500
Start
Receive reference signal (RS) from eNB
502
Obtain received power with respect to the RS
504
506
Power < threshold?
Yes
No
508
Packets decodable?
Yes
No
End
510
Other CC(s) available?
No
Yes
512
Select a CC to switch to
514
Switch to the selected CC
End
515
Other CCs with power > threshold?
Yes
No
516
Switch to another eNB
End

FIG. 5

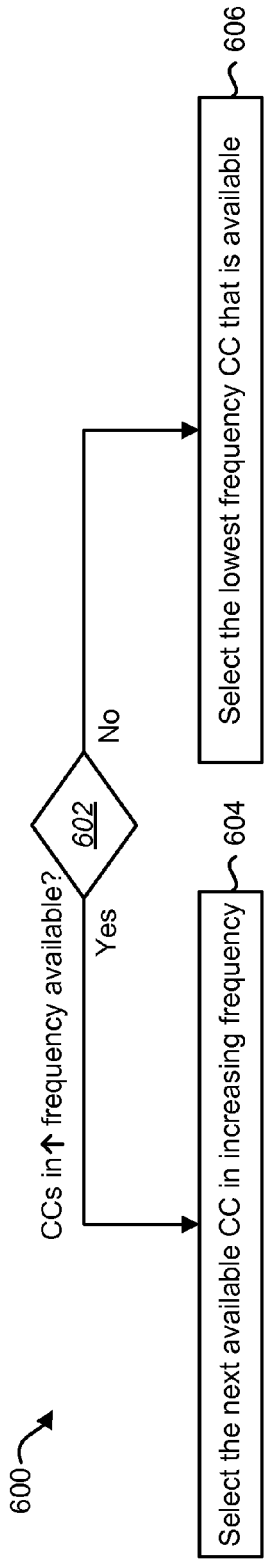

600
CCs in↑ frequency available?
602
Yes
No
Select the next available CC in increasing frequency
604
Select the lowest frequency CC that is available
606

FIG. 6

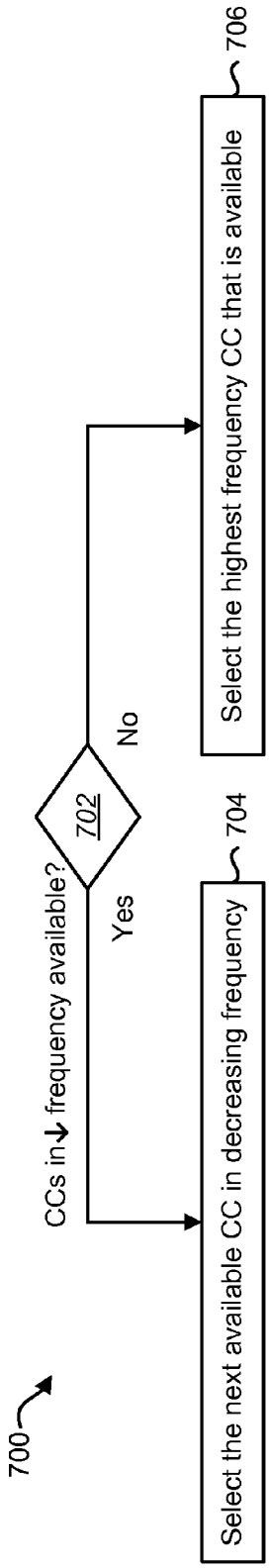

700
CCs in↓ frequency available?
702
Yes
No
Select the next available CC in decreasing frequency
704
Select the highest frequency CC that is available
706

FIG. 7

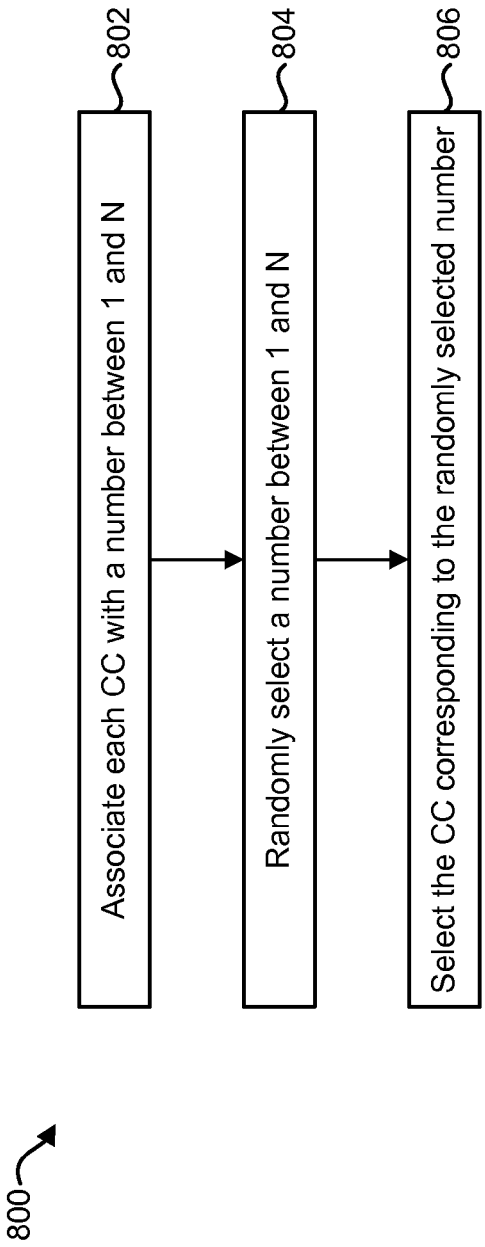

800
802
Associate each CC with a number between 1 and N
804
Randomly select a number between 1 and N
806
Select the CC corresponding to the randomly selected number

FIG. 8

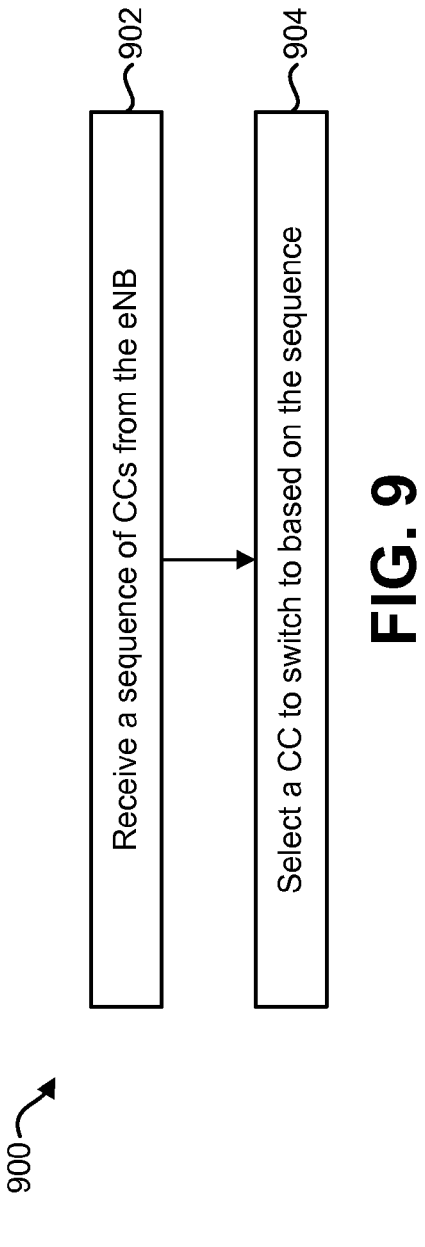

900
902
Receive a sequence of CCs from the eNB
904
Select a CC to switch to based on the sequence

FIG. 9

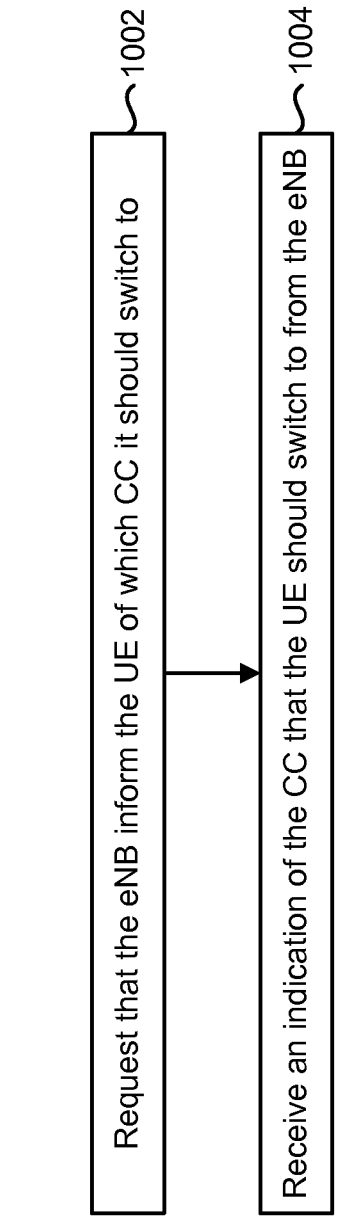

1000
1002
Request that the eNB inform the UE of which CC it should switch to
1004
Receive an indication of the CC that the UE should switch to from the eNB

FIG. 10

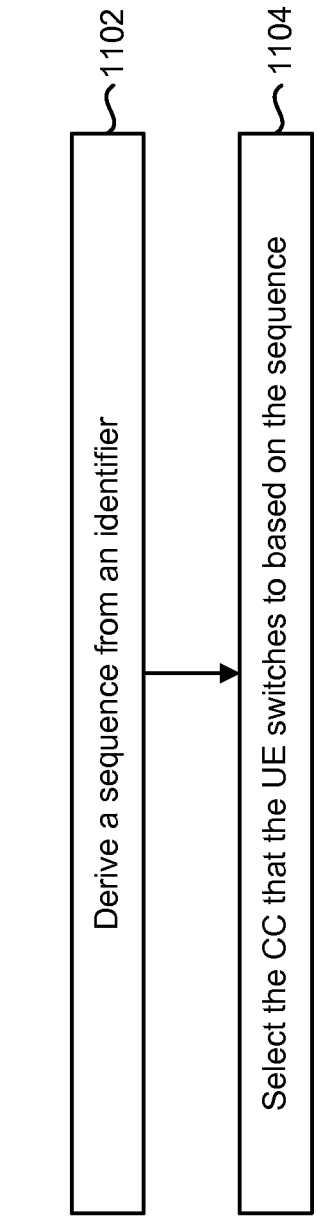

1100
1102
Derive a sequence from an identifier
1104
Select the CC that the UE switches to based on the sequence

FIG. 11

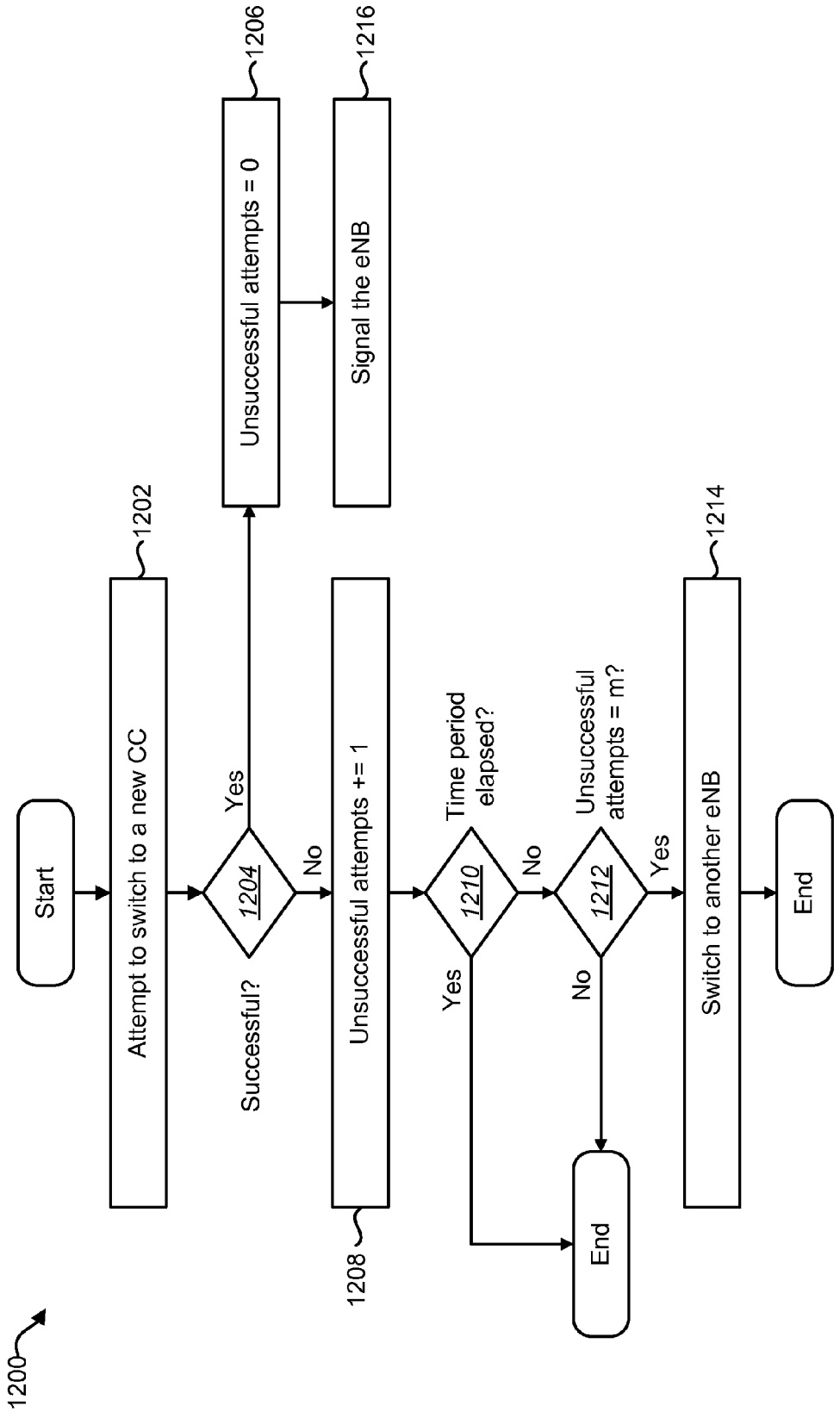

1200
Start
Attempt to switch to a new CC
1202
1204
Successful?
Yes
No
Unsuccessful attempts = 0
1206
Signal the eNB
1216
Unsuccessful attempts += 1
1208
1210
Time period elapsed?
Yes
No
End
1212
Unsuccessful attempts = m?
No
Yes
Switch to another eNB
1214
End

FIG. 12

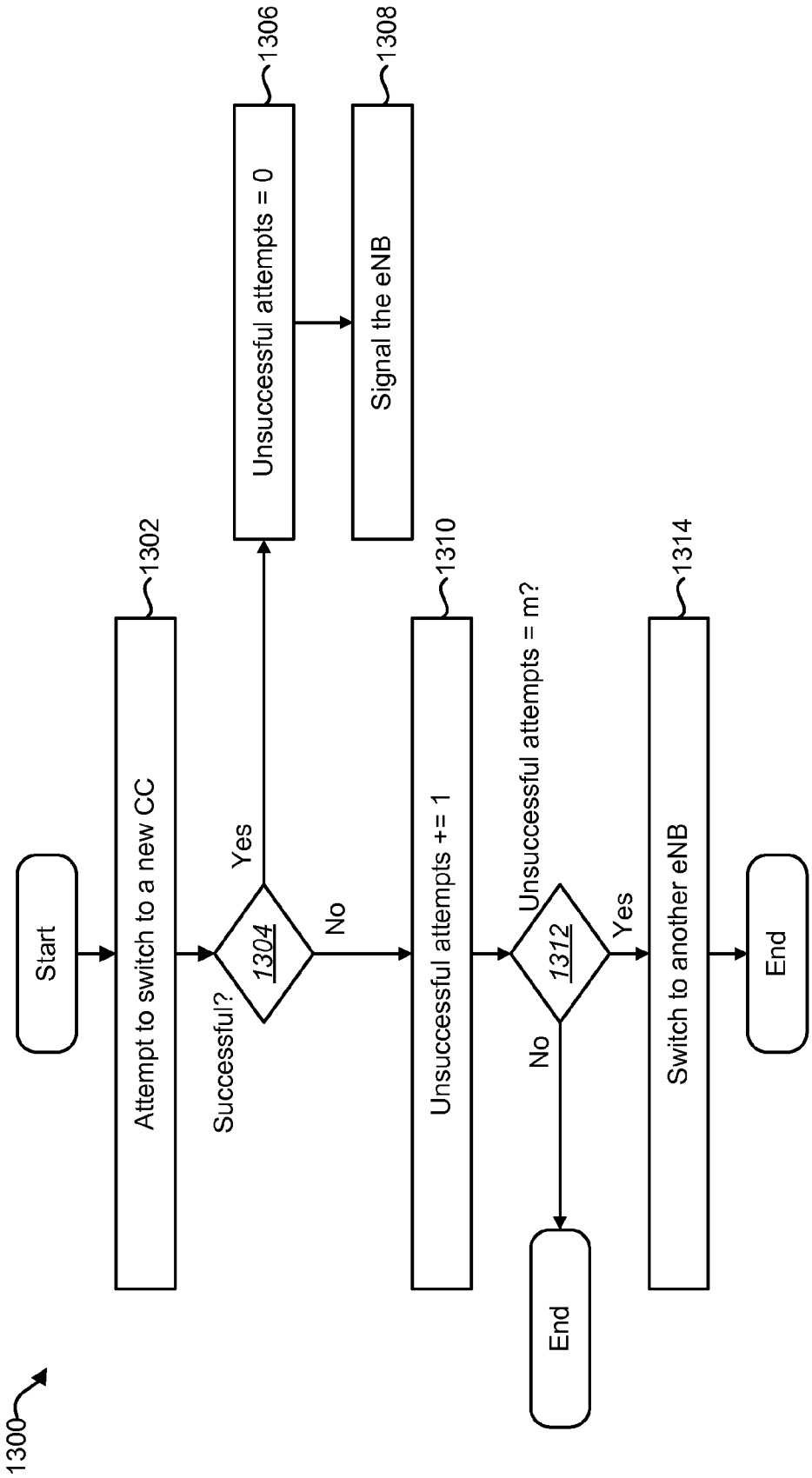

1300
Start
Attempt to switch to a new CC
1302
Successful?
1304
Yes
No
Unsuccessful attempts = 0
1306
Signal the eNB
1308
Unsuccessful attempts += 1
1310
Unsuccessful attempts = m?
1312
No
Yes
End
Switch to another eNB
1314
End

FIG. 13

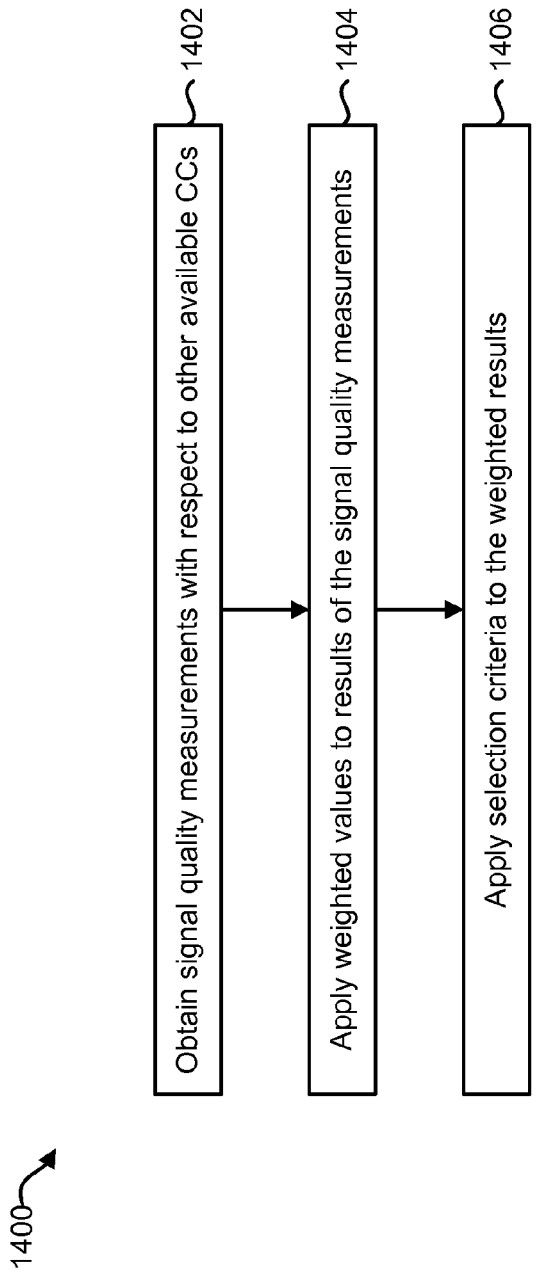

1400
1402
Obtain signal quality measurements with respect to other available CCs
1404
Apply weighted values to results of the signal quality measurements
1406
Apply selection criteria to the weighted results

FIG. 14

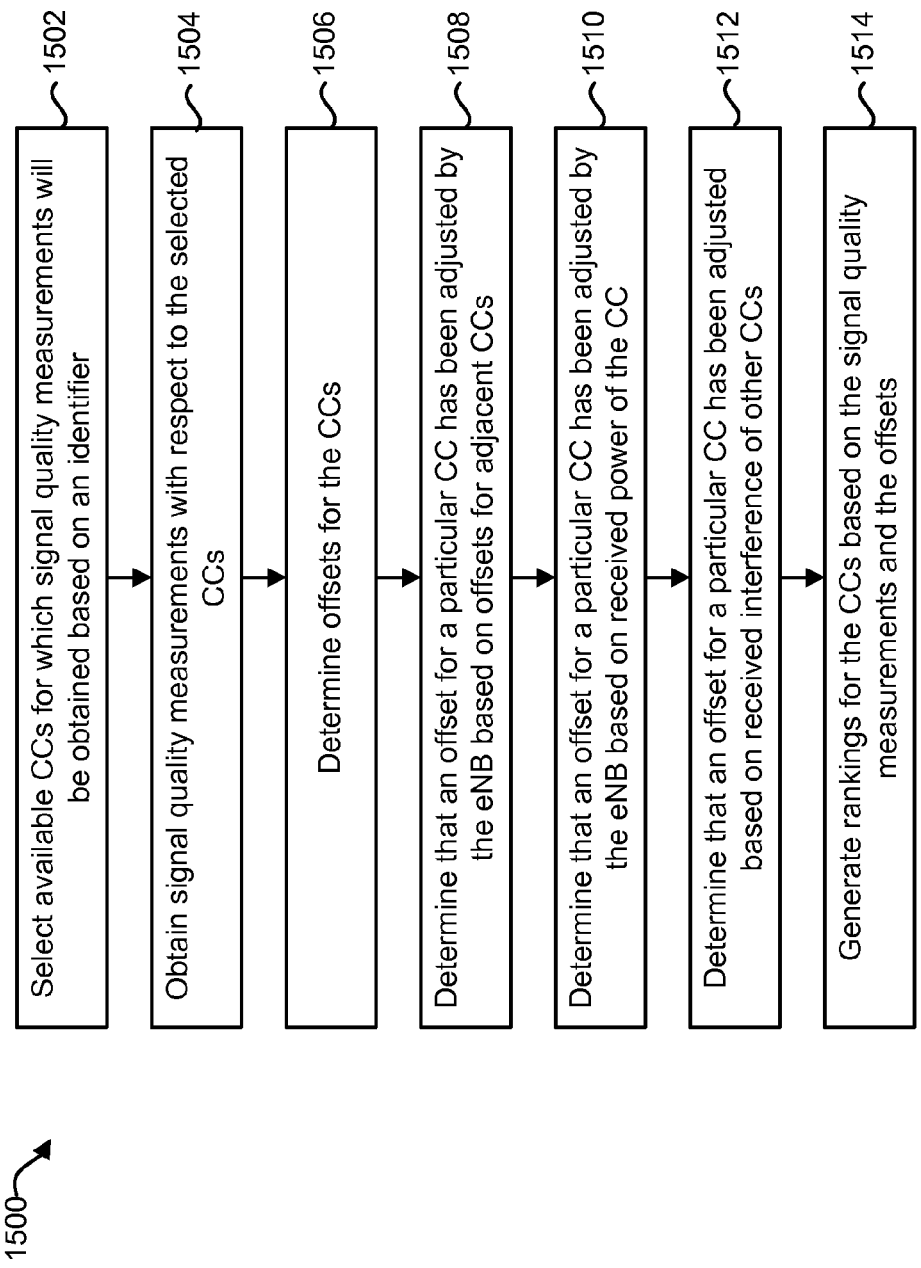

1500
1502
Select available CCs for which signal quality measurements will be obtained based on an identifier
1504
Obtain signal quality measurements with respect to the selected CCs
1506
Determine offsets for the CCs
1508
Determine that an offset for a particular CC has been adjusted by the eNB based on offsets for adjacent CCs
1510
Determine that an offset for a particular CC has been adjusted by the eNB based on received power of the CC
1512
Determine that an offset for a particular CC has been adjusted based on received interference of other CCs
1514
Generate rankings for the CCs based on the signal quality measurements and the offsets

FIG. 15

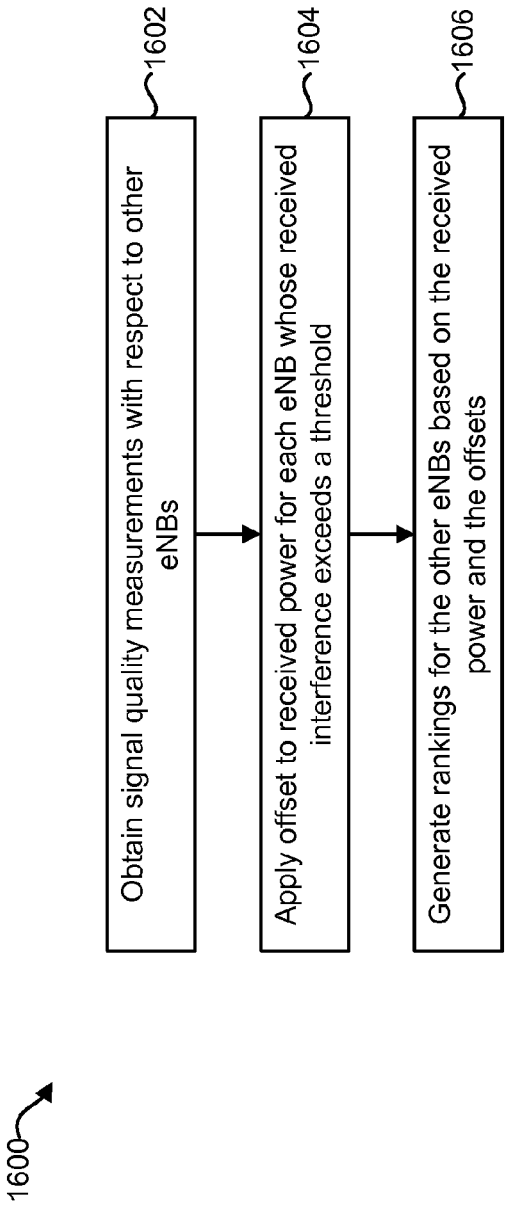

1600
1602
Obtain signal quality measurements with respect to other eNBs
1604
Apply offset to received power for each eNB whose received interference exceeds a threshold
1606
Generate rankings for the other eNBs based on the received power and the offsets

FIG. 16

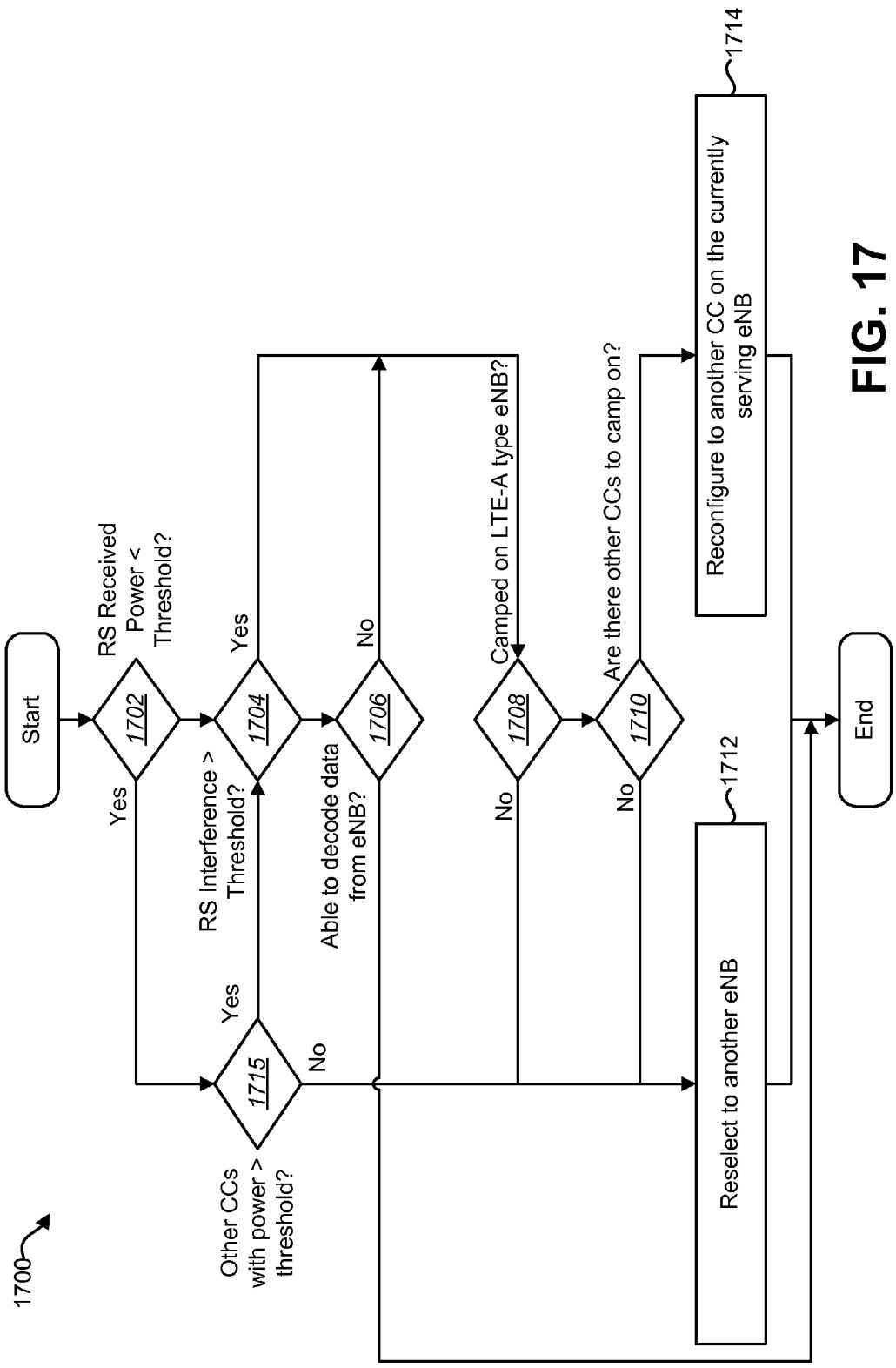

1700
Start
RS Received Power < Threshold?
1702
Yes
RS Interference > Threshold?
1704
Yes
Other CCs with power > threshold?
1715
Yes
No
Able to decode data from eNB?
1706
No
Camped on LTE-A type eNB?
1708
No
Are there other CCs to camp on?
1710
No
Reconfigure to another CC on the currently serving eNB
1714
Reselect to another eNB
1712
End

FIG. 17

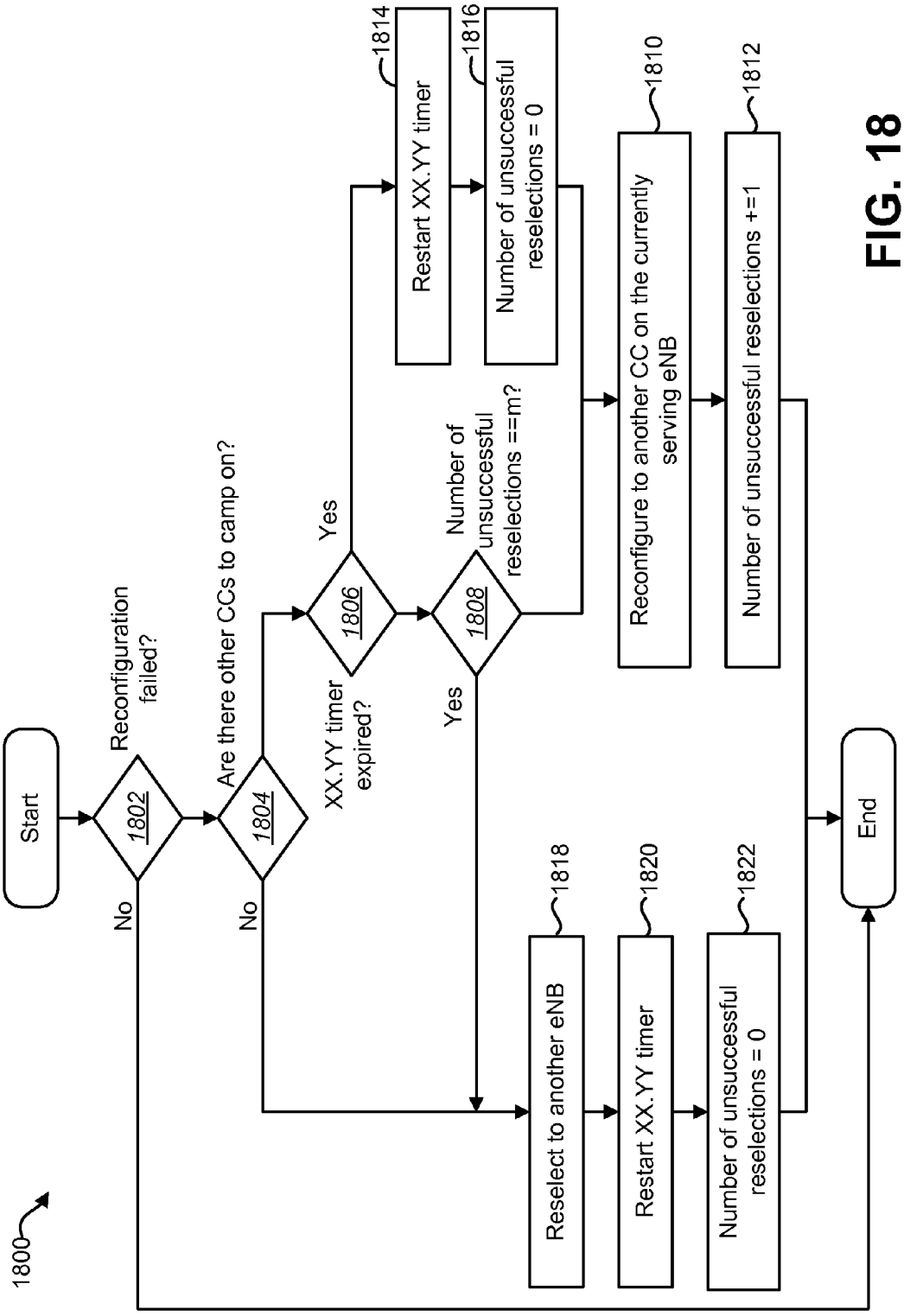

1800
Start
Reconfiguration failed?
1802
No
Are there other CCs to camp on?
1804
No
XX.YY timer expired?
1806
Yes
Restart XX.YY timer
1814
Number of unsuccessful reselections ==m?
1808
Yes
Number of unsuccessful reselections = 0
1816
Reconfigure to another CC on the currently serving eNB
1810
Number of unsuccessful reselections +=1
1812
Reselect to another eNB
1818
Restart XX.YY timer
1820
Number of unsuccessful reselections = 0
1822
End

FIG. 18

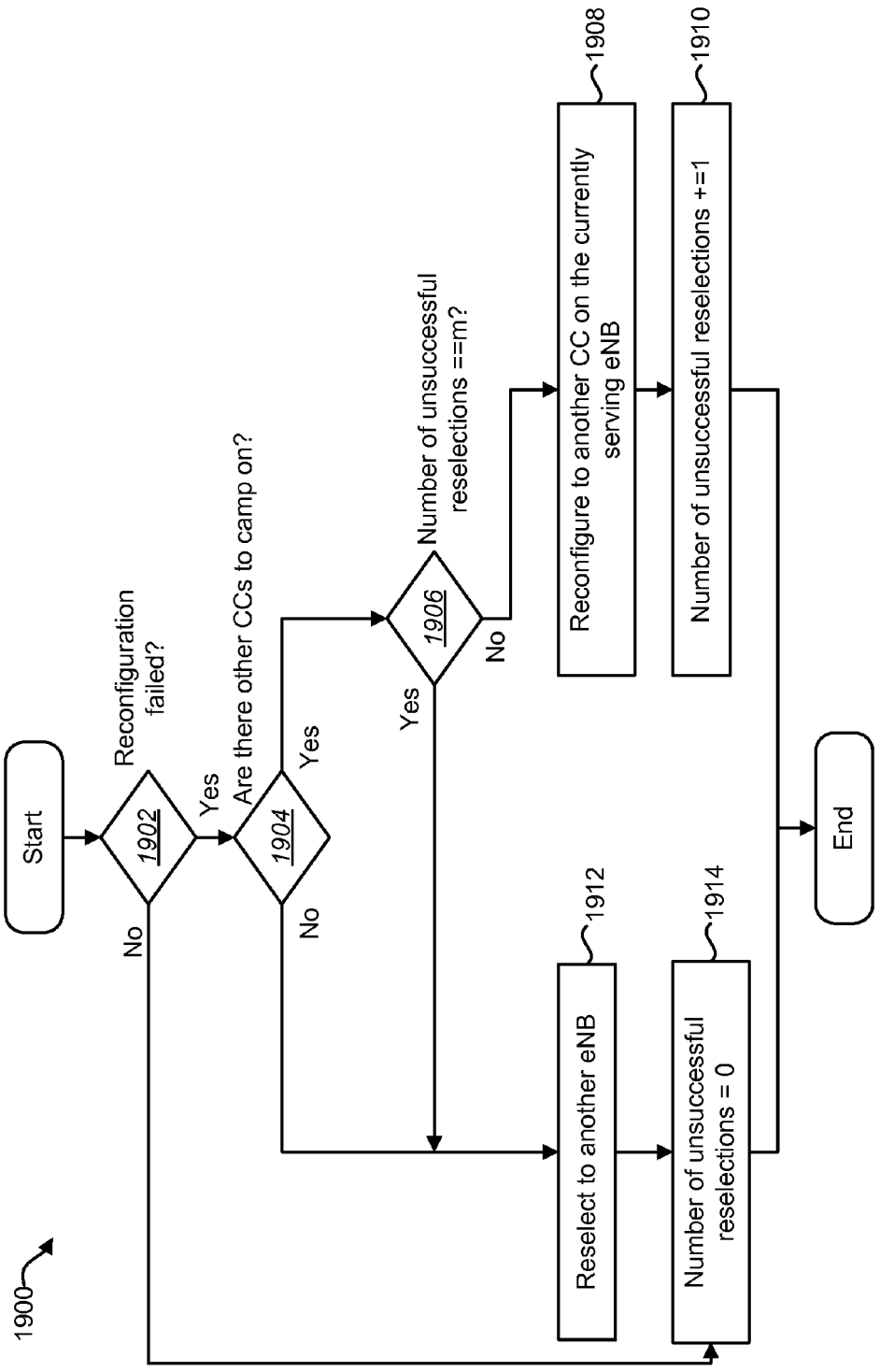

1900
Start
Reconfiguration failed?
1902
No
Yes
Are there other CCs to camp on?
1904
No
Yes
Number of unsuccessful reselections ==m?
1906
Yes
No
Reconfigure to another CC on the currently serving eNB
1908
Number of unsuccessful reselections +=1
1910
Reselect to another eNB
1912
Number of unsuccessful reselections = 0
1914
End

FIG. 19

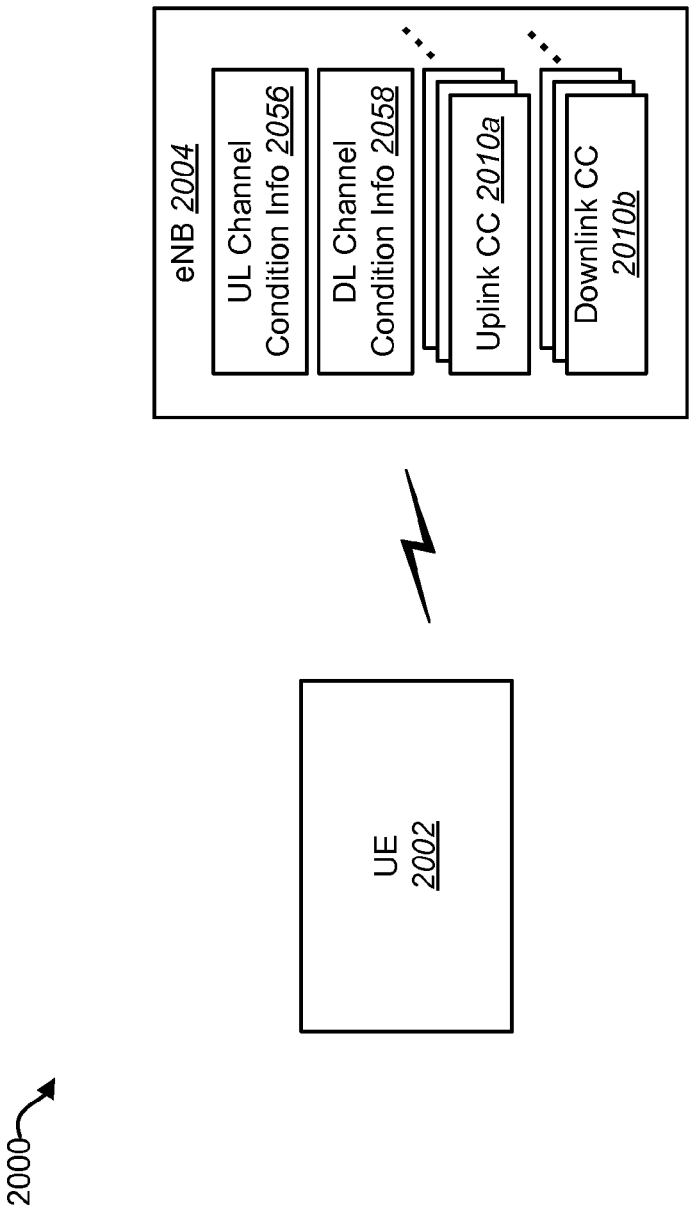

2000
UE
2002
eNB 2004
UL Channel Condition Info 2056
DL Channel Condition Info 2058
Uplink CC 2010a
Downlink CC 2010b

FIG. 20

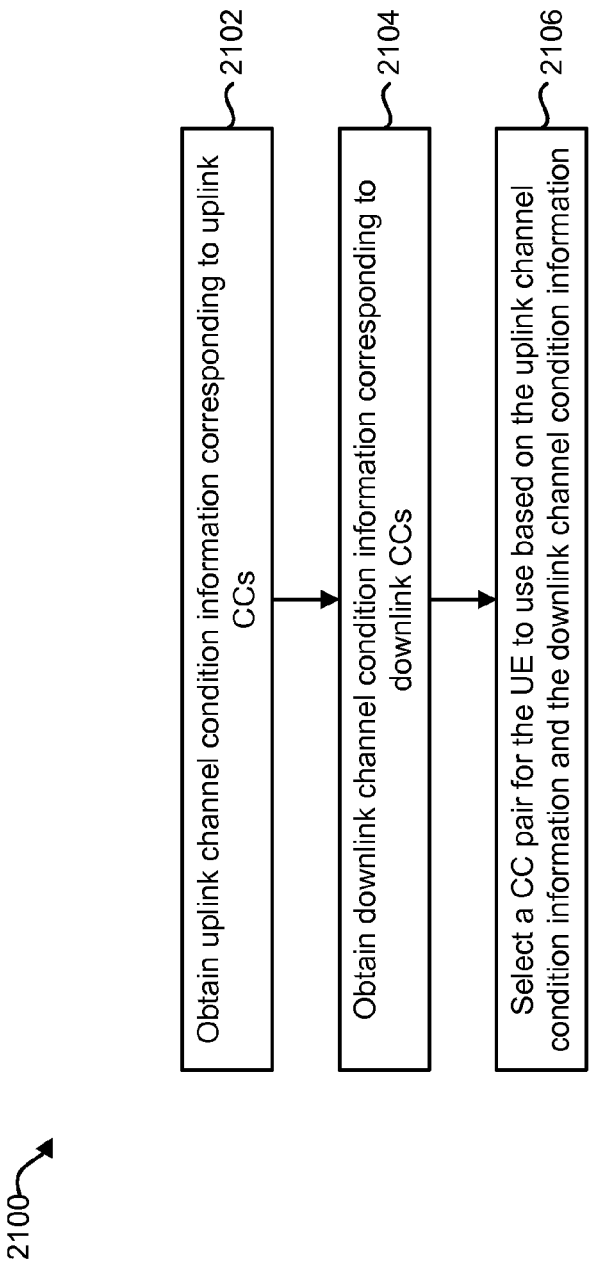

2100
2102
Obtain uplink channel condition information corresponding to uplink CCs
2104
Obtain downlink channel condition information corresponding to downlink CCs
2106
Select a CC pair for the UE to use based on the uplink channel condition information and the downlink channel condition information

FIG. 21

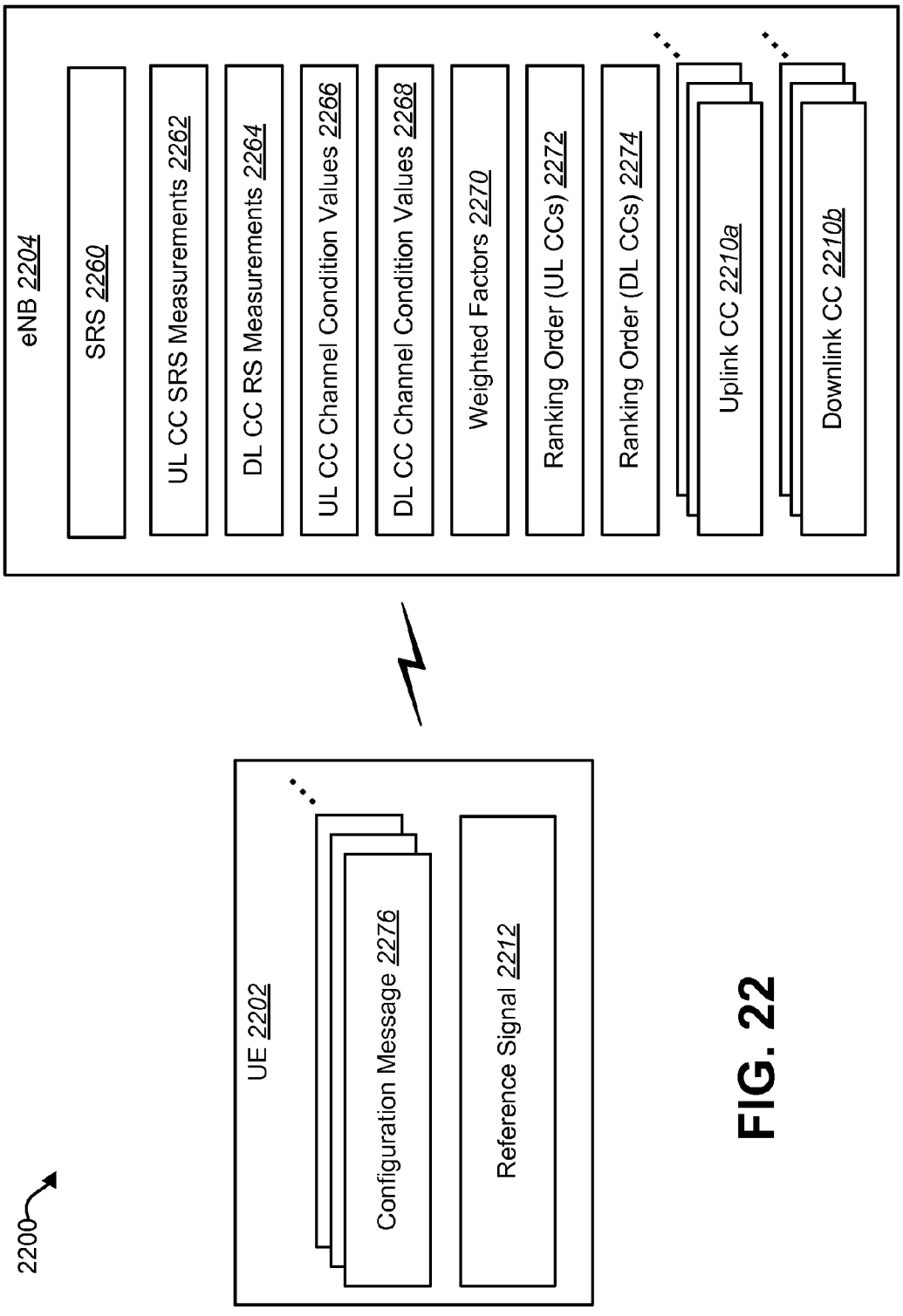

2200
UE 2202
Configuration Message 2276
Reference Signal 2212
eNB 2204
SRS 2260
UL CC SRS Measurements 2262
DL CC RS Measurements 2264
UL CC Channel Condition Values 2266
DL CC Channel Condition Values 2268
Weighted Factors 2270
Ranking Order (UL CCs) 2272
Ranking Order (DL CCs) 2274
Uplink CC 2210a
Downlink CC 2210b

FIG. 22

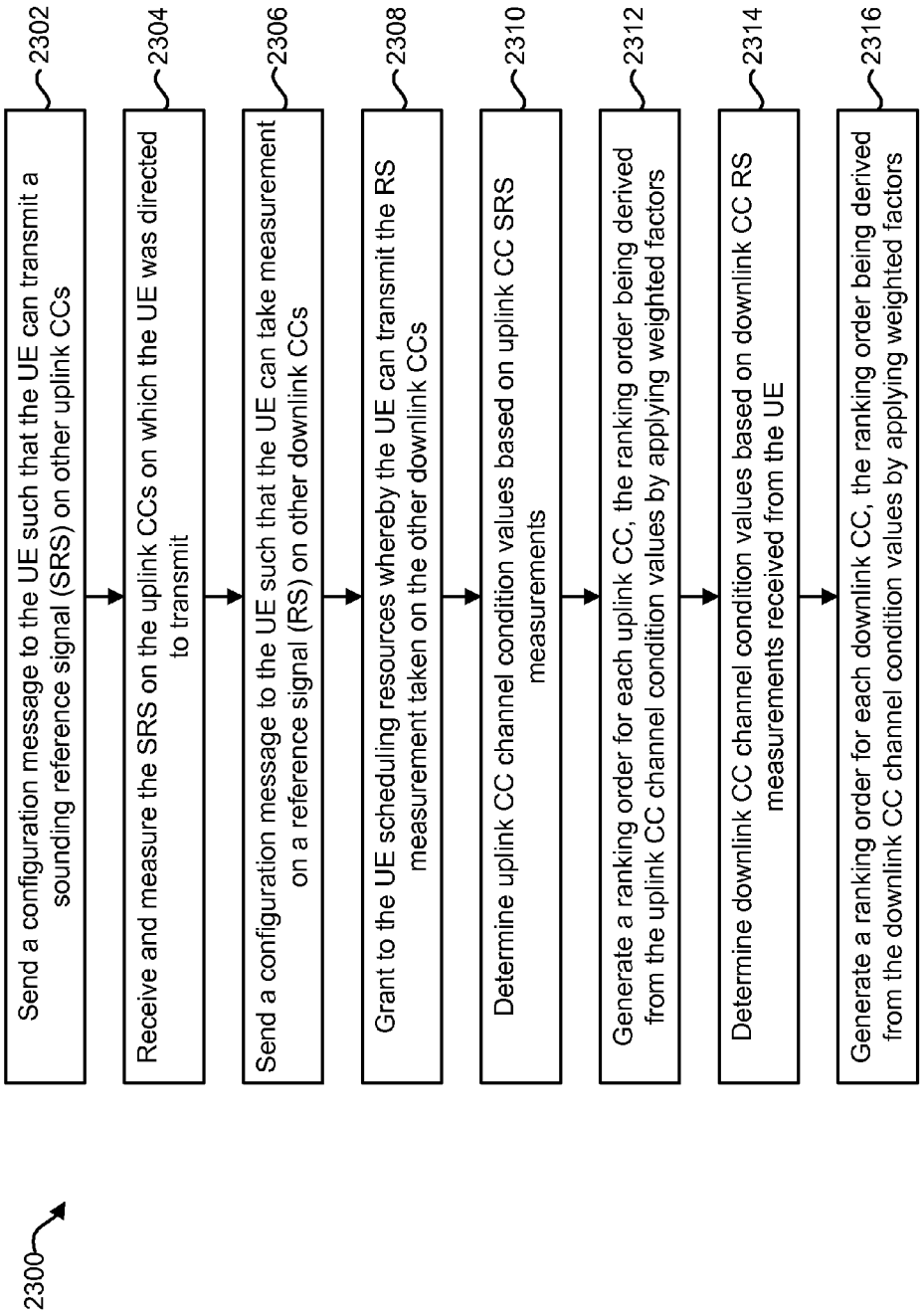

2300
2302
Send a configuration message to the UE such that the UE can transmit a sounding reference signal (SRS) on other uplink CCs
2304
Receive and measure the SRS on the uplink CCs on which the UE was directed to transmit
2306
Send a configuration message to the UE such that the UE can take measurement on a reference signal (RS) on other downlink CCs
2308
Grant to the UE scheduling resources whereby the UE can transmit the RS measurement taken on the other downlink CCs
2310
Determine uplink CC channel condition values based on uplink CC SRS measurements
2312
Generate a ranking order for each uplink CC, the ranking order being derived from the uplink CC channel condition values by applying weighted factors
2314
Determine downlink CC channel condition values based on downlink CC RS measurements received from the UE
2316
Generate a ranking order for each downlink CC, the ranking order being derived from the downlink CC channel condition values by applying weighted factors

FIG. 23

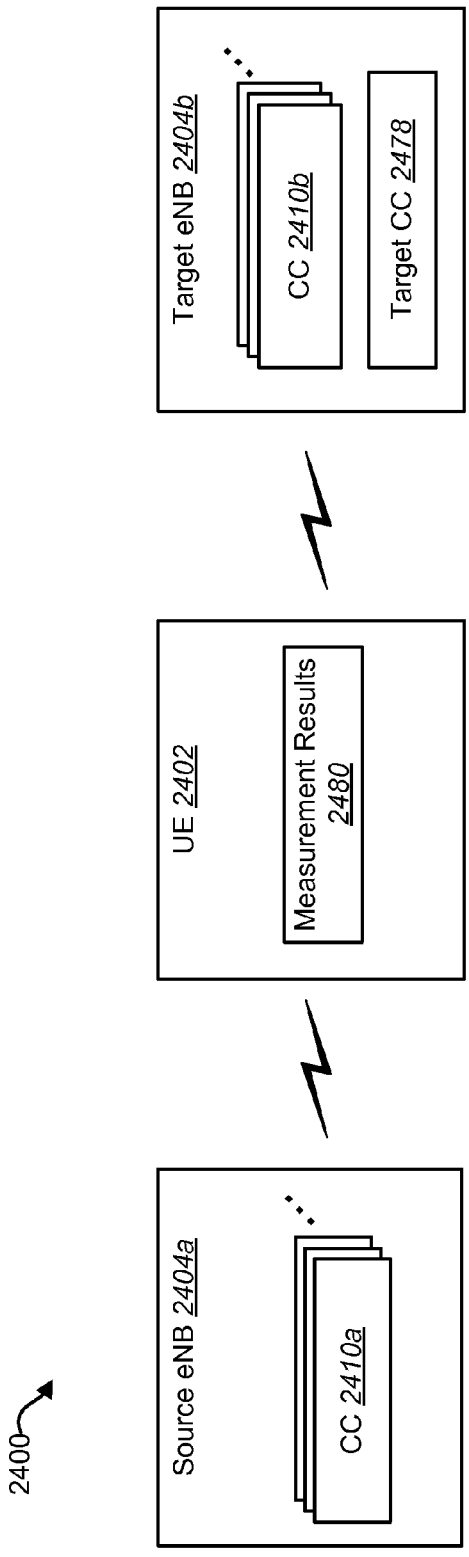

2400
Source eNB 2404a
CC 2410a
UE 2402
Measurement Results 2480
Target eNB 2404b
CC 2410b
Target CC 2478

FIG. 24

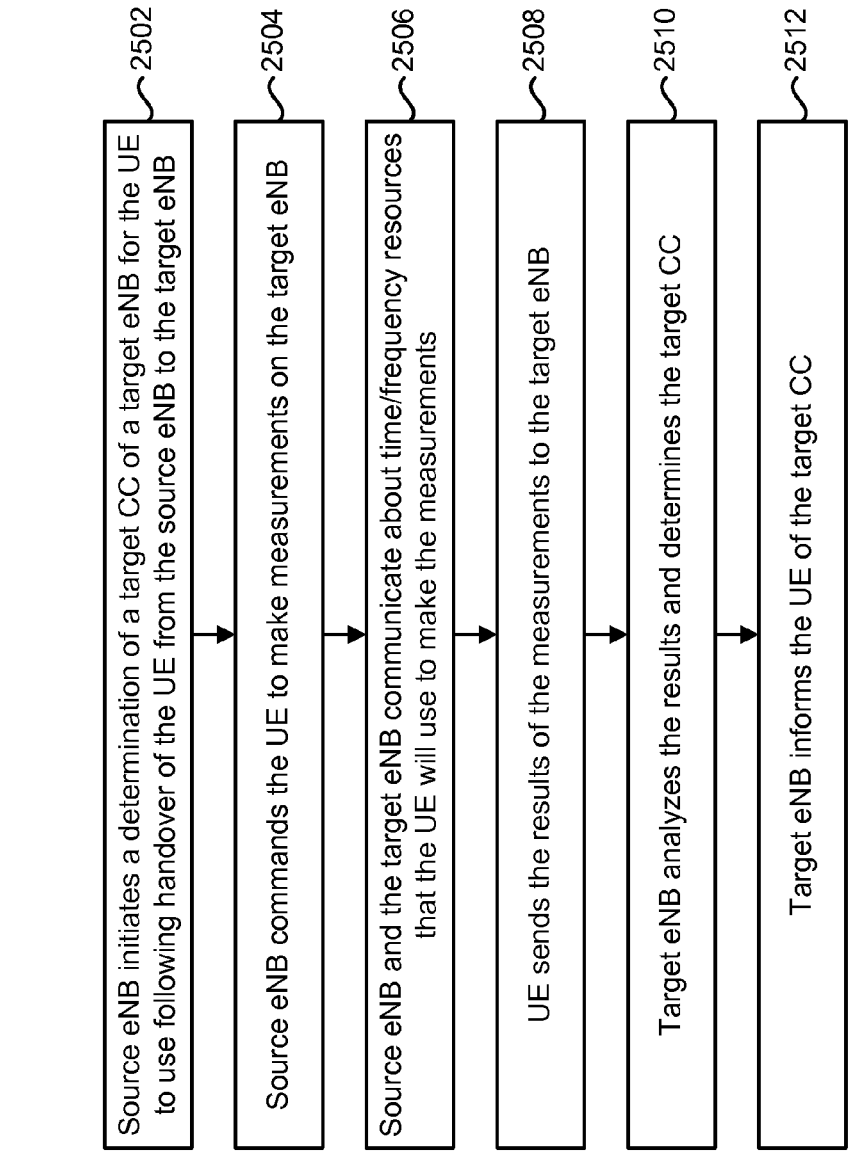

2500
2502
Source eNB initiates a determination of a target CC of a target eNB for the UE to use following handover of the UE from the source eNB to the target eNB
2504
Source eNB commands the UE to make measurements on the target eNB
2506
Source eNB and the target eNB communicate about time/frequency resources that the UE will use to make the measurements
2508
UE sends the results of the measurements to the target eNB
2510
Target eNB analyzes the results and determines the target CC
2512
Target eNB informs the UE of the target CC

FIG. 25

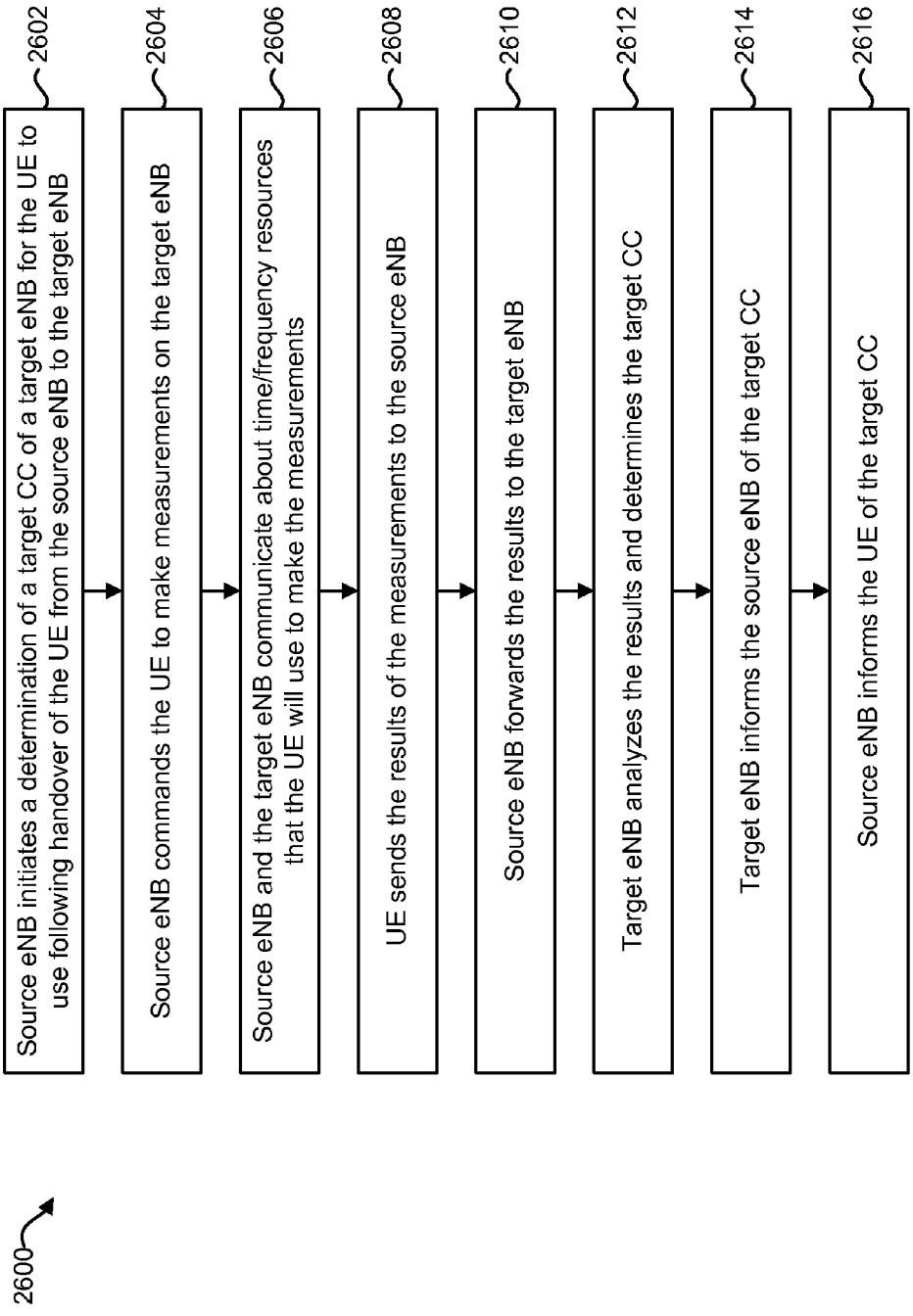

2600
2602
Source eNB initiates a determination of a target CC of a target eNB for the UE to use following handover of the UE from the source eNB to the target eNB
2604
Source eNB commands the UE to make measurements on the target eNB
2606
Source eNB and the target eNB communicate about time/frequency resources that the UE will use to make the measurements
2608
UE sends the results of the measurements to the source eNB
2610
Source eNB forwards the results to the target eNB
2612
Target eNB analyzes the results and determines the target CC
2614
Target eNB informs the source eNB of the target CC
2616
Source eNB informs the UE of the target CC

FIG. 26

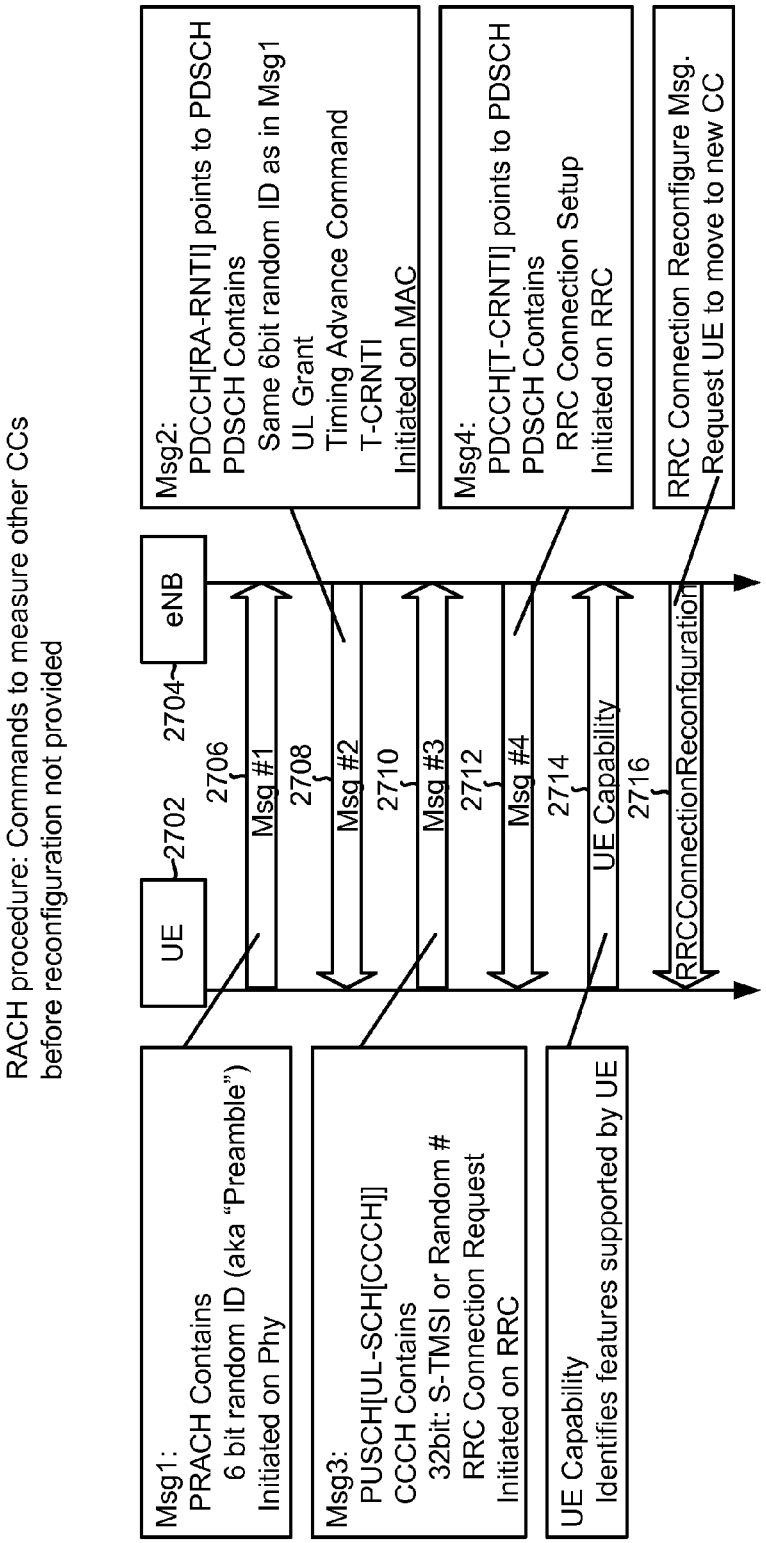

RACH procedure: Commands to measure other CCs
before reconfiguration not provided
UE
2702
eNB
2704
2706
Msg #1
2708
Msg #2
2710
Msg #3
2712
Msg #4
2714
UE Capability
2716
RRCConnectionReconfguration
Msg1:
PRACH Contains
6 bit random ID (aka "Preamble")
Initiated on Phy
Msg2:
PDCCH[RA-RNTI] points to PDSCH
PDSCH Contains
Same 6bit random ID as in Msg1
UL Grant
Timing Advance Command
T-CRNTI
Initiated on MAC
Msg3:
PUSCH[UL-SCH[CCCH]]
CCCH Contains
32bit: S-TMSI or Random #
RRC Connection Request
Initiated on RRC
Msg4:
PDCCH[T-CRNTI] points to PDSCH
PDSCH Contains
RRC Connection Setup
Initiated on RRC
UE Capability
Identifies features supported by UE
RRC Connection Reconfigure Msg.
Request UE to move to new CC

FIG. 27

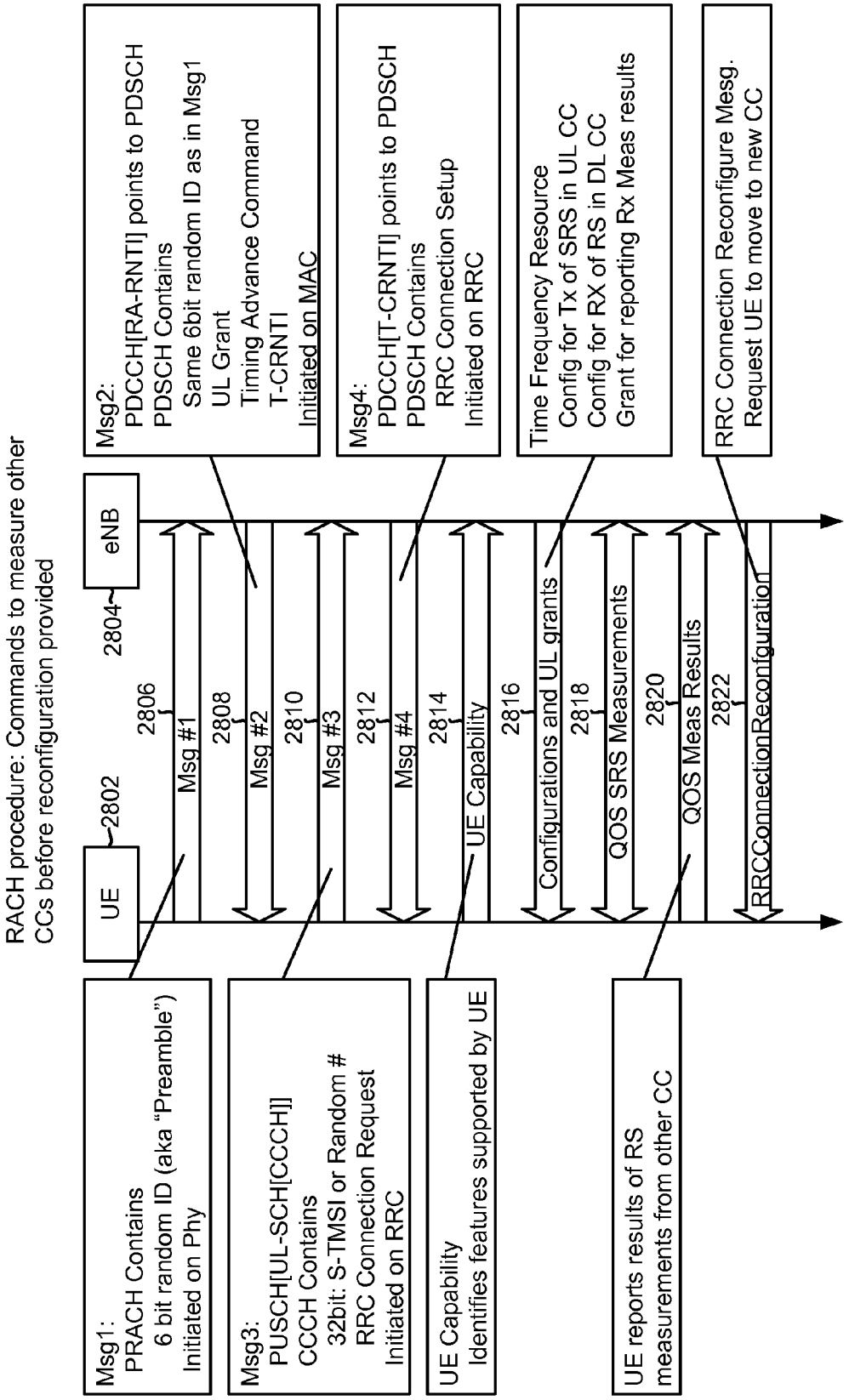

RACH procedure: Commands to measure other CCs before reconfiguration provided
UE
2802
eNB
2804
2806
Msg #1
2808
Msg #2
2810
Msg #3
2812
Msg #4
2814
UE Capability
2816
Configurations and UL grants
2818
QOS SRS Measurements
2820
QOS Meas Results
2822
RRCConnectionReconfguration
Msg1:
PRACH Contains
6 bit random ID (aka "Preamble")
Initiated on Phy
Msg3:
PUSCH[UL-SCH[CCCH]]
CCCH Contains
32bit: S-TMSI or Random #
RRC Connection Request
Initiated on RRC
UE Capability
Identifies features supported by UE
UE reports results of RS measurements from other CC
Msg2:
PDCCH[RA-RNTI] points to PDSCH
PDSCH Contains
Same 6bit random ID as in Msg1
UL Grant
Timing Advance Command
T-CRNTI
Initiated on MAC
Msg4:
PDCCH[T-CRNTI] points to PDSCH
PDSCH Contains
RRC Connection Setup
Initiated on RRC
Time Frequency Resource
Config for Tx of SRS in UL CC
Config for RX of RS in DL CC
Grant for reporting Rx Meas results
RRC Connection Reconfigure Mesg.
Request UE to move to new CC

FIG. 28

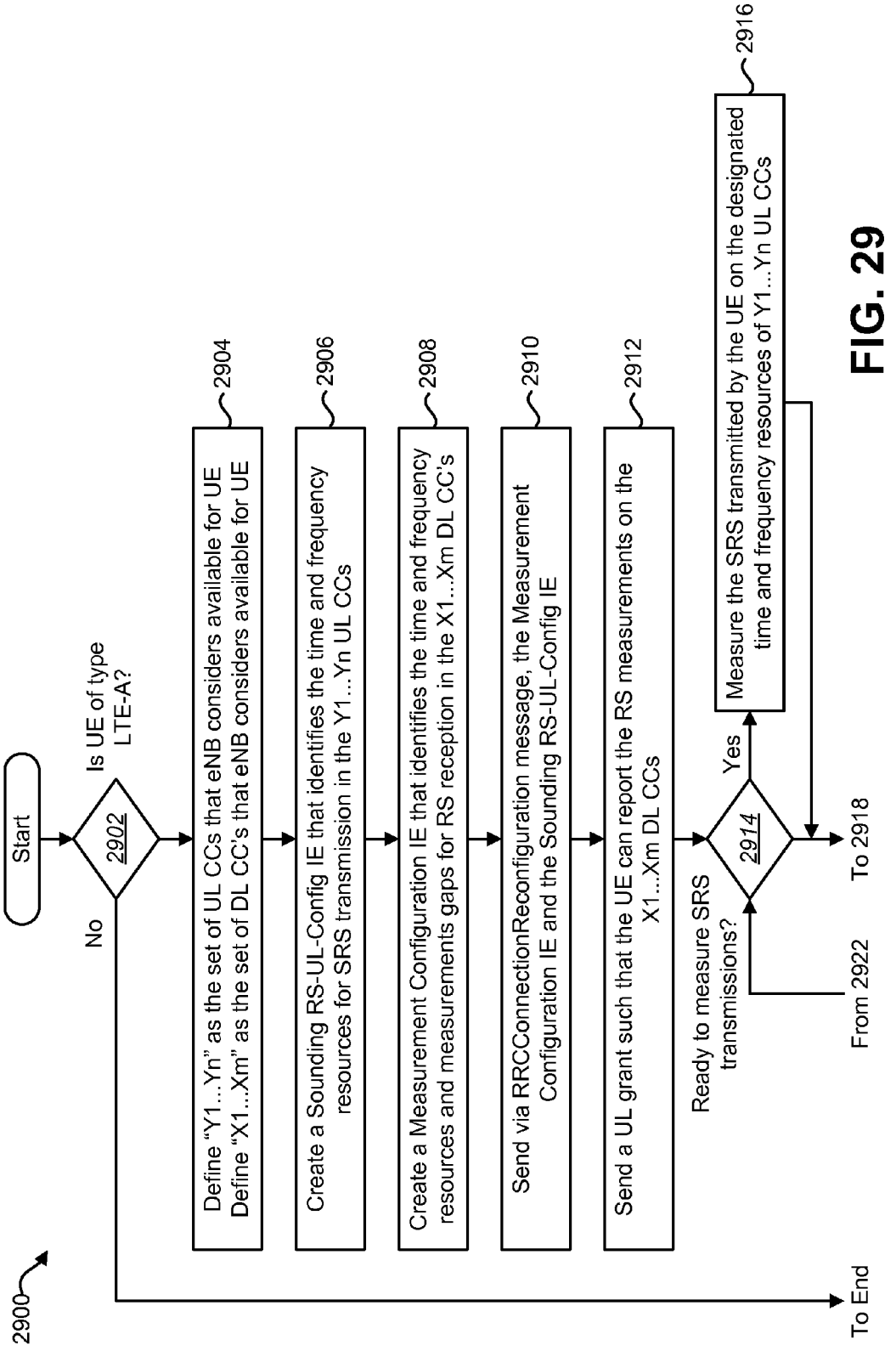

2900
Start
Is UE of type LTE-A?
2902
No
Yes
To End
Define "Y1...Yn" as the set of UL CCs that eNB considers available for UE
Define "X1...Xm" as the set of DL CC's that eNB considers available for UE
2904
Create a Sounding RS-UL-Config IE that identifies the time and frequency resources for SRS transmission in the Y1...Yn UL CCs
2906
Create a Measurement Configuration IE that identifies the time and frequency resources and measurements gaps for RS reception in the X1...Xm DL CC's
2908
Send via RRCConnectionReconfiguration message, the Measurement Configuration IE and the Sounding RS-UL-Config IE
2910
Send a UL grant such that the UE can report the RS measurements on the X1...Xm DL CCs
2912
Ready to measure SRS transmissions?
2914
From 2922
To 2918
Measure the SRS transmitted by the UE on the designated time and frequency resources of Y1...Yn UL CCs
2916

FIG. 29

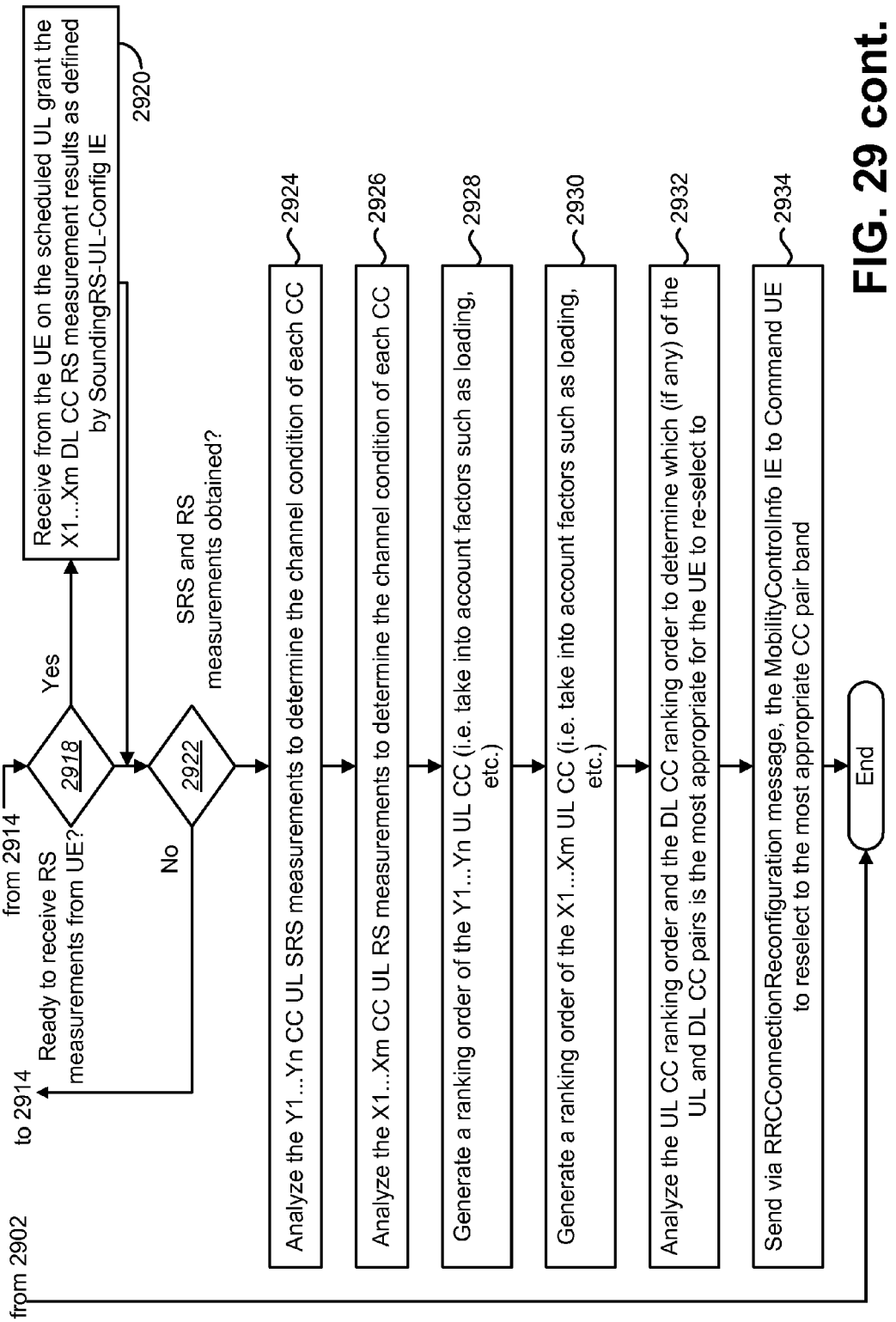

from 2902
from 2914
to 2914
Ready to receive RS measurements from UE?
2918
Yes
No
Receive from the UE on the scheduled UL grant the X1...Xm DL CC RS measurement results as defined by SoundingRS-UL-Config IE
2920
SRS and RS measurements obtained?
2922
Analyze the Y1...Yn CC UL SRS measurements to determine the channel condition of each CC
2924
Analyze the X1...Xm CC UL RS measurements to determine the channel condition of each CC
2926
Generate a ranking order of the Y1...Yn UL CC (i.e. take into account factors such as loading, etc.)
2928
Generate a ranking order of the X1...Xm UL CC (i.e. take into account factors such as loading, etc.)
2930
Analyze the UL CC ranking order and the DL CC ranking order to determine which (if any) of the UL and DL CC pairs is the most appropriate for the UE to re-select to
2932
Send via RRCConnectionReconfiguration message, the MobilityControlInfo IE to Command UE to reselect to the most appropriate CC pair band
2934
End

FIG. 29 cont.

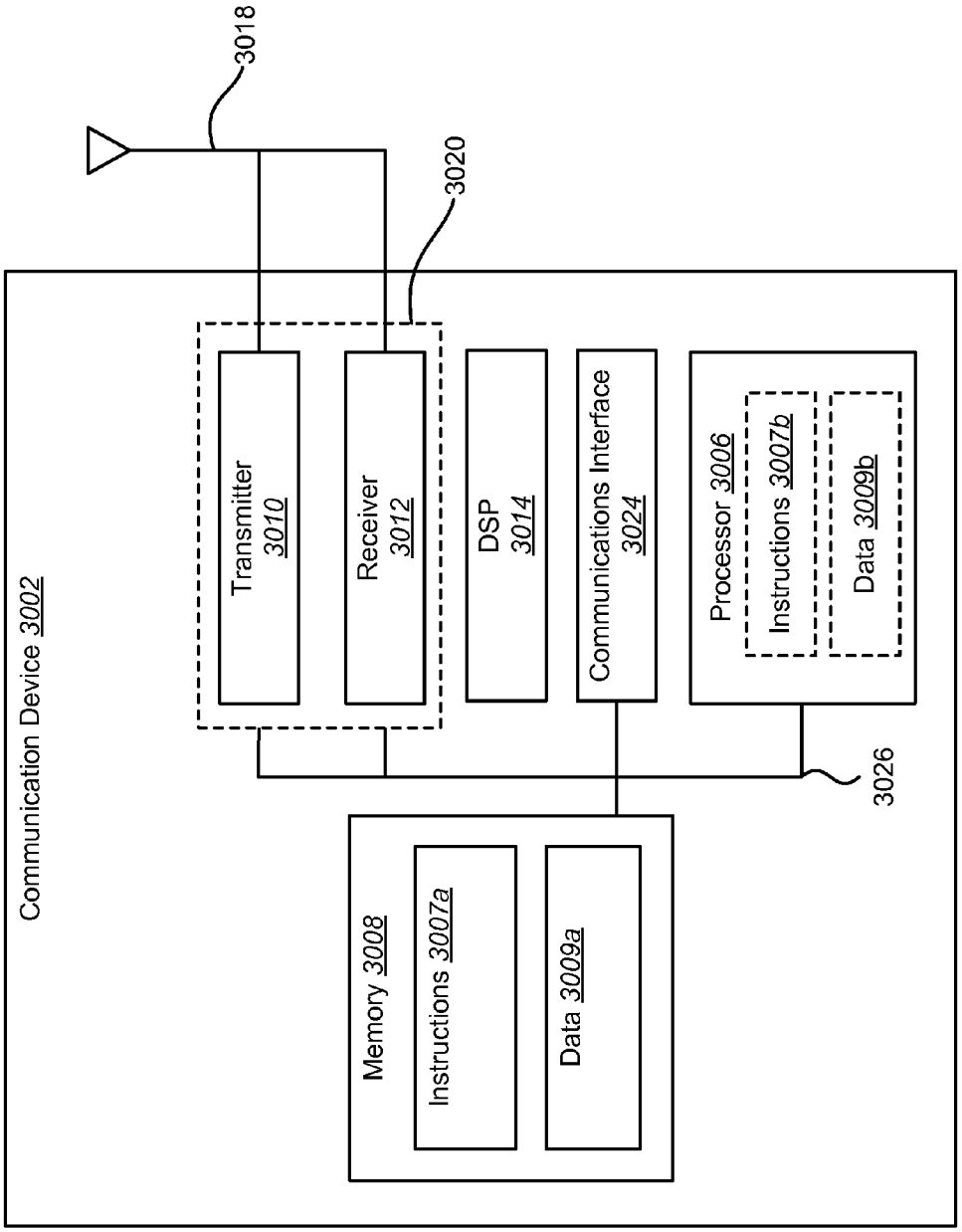

3018
3020
Communication Device 3002
Transmitter 3010
Receiver 3012
DSP 3014
Communications Interface 3024
Processor 3006
Instructions 3007b
Data 3009b
3026
Memory 3008
Instructions 3007a
Data 3009a

FIG. 30

SYSTEMS AND METHODS FOR COMPONENT CARRIER SELECTION IN A WIRELESS COMMUNICATION SYSTEM

TECHNICAL FIELD

The present disclosure relates generally to wireless communication systems. More specifically, the present disclosure relates to systems and methods for component carrier selection in a wireless communication system.

BACKGROUND

Wireless communication systems have become an important means by which many people worldwide have come to communicate. A wireless communication system may provide communication for a number of mobile stations, each of which may be serviced by one or more base stations.

The 3rd Generation Partnership Project, also referred to as "3GPP," is a collaboration agreement that aims to define globally applicable technical specifications and technical reports for third and fourth generation wireless communication systems. The 3GPP may define specifications for the next generation mobile networks, systems, and devices. In 3GPP specifications, a mobile station is typically referred to as a user equipment (UE), and a base station is typically referred to as a Node B or an evolved Node B (eNB).

3GPP Long Term Evolution (LTE) is the name given to a project to improve the Universal Mobile Telecommunications System (UMTS) mobile phone or device standard to cope with future requirements. In one aspect, UMTS has been modified to provide support and specification for the Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN). LTE-Advanced is the next generation of LTE.

3GPP LTE-Advanced specifications will include functionality that will enable separate (possibly non-contiguous) bands of spectrum to be aggregated via partitioning into component carriers. Each component carrier (CC) may include 2.5 MHz to 20 MHz of bandwidth. The reasoning for having a maximum partition of 20 MHz is to provide a mechanism for backward capability to LTE Release 8 and Release 9 UEs. The systems and methods disclosed herein relate generally to component carrier selection in a wireless communication system (e.g., an LTE-Advanced system).

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a wireless communication system in which at least some of the methods disclosed herein may be implemented;

FIG. **2** illustrates a method for component carrier selection in the wireless communication system of FIG. **1**;

FIG. **3** illustrates a wireless communication system in which at least some of the methods disclosed herein may be implemented;

FIG. **4** illustrates a method for component carrier selection in the wireless communication system of FIG. **3**;

FIG. **5** illustrates another method for component carrier selection in the wireless communication system of FIG. **3**;

FIG. **6** illustrates a method for selecting a component carrier for a UE to switch to;

FIG. **7** illustrates another method for selecting a component carrier for a UE to switch to;

FIG. **8** illustrates another method for selecting a component carrier for a UE to switch to;

FIG. **9** illustrates another method for selecting a component carrier for a UE to switch to;

FIG. **10** illustrates another method for selecting a component carrier for a UE to switch to;

FIG. **11** illustrates another method for selecting a component carrier for a UE to switch to;

FIG. **12** illustrates a method that may be performed by a UE in connection with attempting to switch to another component carrier;

FIG. **13** illustrates another method that may be performed by a UE in connection with attempting to switch to another component carrier;

FIG. **14** illustrates another method for selecting a component carrier for a UE to switch to;

FIG. **15** illustrates another method for selecting a component carrier for a UE to switch to;

FIG. **16** illustrates a method for selecting an eNB for a UE to switch to;

FIG. **17** illustrates a method that may be implemented in a UE in order to determine reselection to another eNB or reconfiguration to another component carrier;

FIG. **18** illustrates a method that may be implemented in a UE in order to determine if reselection to another eNB is necessary after a failed reconfiguration;

FIG. **19** illustrates another method that may be implemented in a UE in order to determine if reselection to another eNB is necessary after a failed reconfiguration;

FIG. **20** illustrates another wireless communication system in which at least some of the methods disclosed herein may be implemented;

FIG. **21** illustrates a method for component carrier selection in the wireless communication system of FIG. **20**;

FIG. **22** illustrates another wireless communication system in which at least some of the methods disclosed herein may be implemented;

FIG. **23** illustrates a method for component carrier selection in the wireless communication system of FIG. **22**;

FIG. **24** illustrates another wireless communication system in which at least some of the methods disclosed herein may be implemented;

FIG. **25** illustrates a method for component carrier selection in the wireless communication system of FIG. **24**;

FIG. **26** illustrates another method for component carrier selection in the wireless communication system of FIG. **24**;

FIG. **27** illustrates a RACH procedure, where commands to measure other CCs before reconfiguration are not provided;

FIG. **28** illustrates a RACH procedure, where commands to measure other CCs before reconfiguration are provided;

FIG. **29** illustrates a method that may be performed by an eNB for determining the best CC band pair for a UE; and

FIG. **30** illustrates various components that may be utilized in a communication device.

DETAILED DESCRIPTION

For clarity, the systems and methods disclosed herein will be described using terminology from the 3GPP LTE and LTE-Advanced standards. However, the scope of the present disclosure should not be limited in this regard. The systems and methods disclosed herein may be utilized in other types of wireless communication systems.

As indicated above, the systems and methods disclosed herein relate generally to component carrier (CC) selection in a wireless communication system (e.g., an LTE-Advanced system). Initially, systems and methods will be described that relate to CC selection for a UE that is in idle mode.

An LTE Release 8 UE in idle mode will attempt to reselect to another eNB when it detects via downlink (DL) signaling measurements that the power of the reference signal (RS) has dropped below a threshold. In LTE Release 8, the level of interference that a UE perceives on a data channel is so closely related to RS power, that factoring interference into the reselection algorithm is not necessary. In an LTE-Advanced system, there are new sources of interference such that relying on a strong relationship between RS power and interference is no longer valid. Therefore, the factoring of an interference measurement into the UE reselection algorithm may be beneficial. In an LTE-Advanced system, it is possible for a UE to monitor in idle mode any one of up to 5 CCs (i.e., camp on the CCs). Thus when a UE that is camped on CC[1] detects interference, it does not necessarily mean that the same interferer is affecting CC[n]. Therefore, it is not necessarily desirable to trigger a reselection on the condition of ((RS_Power<Threshold_Power)|| (Interference>Threshold_Interference)).

A method for component carrier (CC) selection is disclosed. A user equipment (UE) that is in idle mode receives a reference signal (RS) from an evolved Node B (eNB). The UE obtains signal quality measurements with respect to the RS. The UE switches to a new CC based on the signal quality measurements. The signal quality measurements may include received power and interference.

The UE may switch to a new CC if the received power is not less than a received power threshold, if the received interference exceeds an interference threshold, and if the eNB has at least one other CC available. Alternatively, the UE may switch to a new CC if the received power does not drop below a received power threshold, if the UE cannot decode data packets sent by the eNB, and if the eNB has at least one other CC available. The UE may signal the eNB when the UE successfully switches to the new CC.

To select the CC that the UE switches to, the UE may select the next available CC in increasing frequency, or if there are not any available CCs in increasing frequency, the UE may select the lowest frequency CC that is available. Alternatively, the UE may select the next available CC in decreasing frequency, or if there are not any available CCs in decreasing frequency, the UE may select the highest frequency CC that is available. As another alternative, the UE may select the CC that the UE switches to by a random selection of a number between 1 and N, where N is the total number of available CCs.

As another alternative, the UE may select the CC that the UE switches to by a sequence of CCs that is signaled by the eNB to the UE. As another alternative, the UE may select the CC that the UE switches to by requesting that the eNB inform the UE of which CC it should switch to, and receiving an indication of the CC that the UE should switch to from the eNB. As another alternative, the UE may select the CC that the UE switches to by a sequence of CCs that is derived from a cell identifier, a UE identifier, etc.

As another alternative, the UE may select the CC that the UE switches to by obtaining signal quality measurements with respect to other available CCs, applying weighted values to results of the signal quality measurements, and applying selection criteria to the weighted results.

As another alternative, the UE may select the CC that the UE switches to by obtaining signal quality measurements with respect to other available CCs, and generating rankings for the other available CCs based on the signal quality measurements and offsets for the CCs. The UE may determine that an offset for a particular CC has been adjusted by the eNB based on offsets for adjacent CCs. Alternatively, the UE may determine that an offset for a particular CC has been adjusted by the eNB based on transmit power of the CC. As another alternative, the UE may determine that an offset for a particular CC has been adjusted by the eNB based on interference levels of other CCs. The rankings may also be generated based on offsets between CCs.

The UE may select the other available CCs for which the signal quality measurements are obtained and the rankings are generated based on a cell-specific identifier. Alternatively, the UE may select the other available CCs for which the signal quality measurements are obtained and the rankings are generated based on a UE-specific identifier.

The UE may obtain signal quality measurements with respect to other eNBs. The signal quality measurements may include received power and received interference. The UE may generate rankings for the other eNBs based on the received power. The UE may apply offsets to the received power for a particular eNB before the ranking is generated if the received interference for that eNB exceeds a threshold.

The UE may switch to another eNB if the UE makes m unsuccessful attempts to switch to a new CC in a defined time period. As another alternative, the UE may switch to another eNB if the UE makes m sequential unsuccessful attempts to switch to a new CC.

A user equipment (UE) that is configured for component carrier (CC) selection while in idle mode is also disclosed. The UE includes a processor, memory in electronic communication with the processor, and instructions stored in the memory. The instructions are executable to receive a reference signal (RS) from an evolved Node B (eNB), obtain signal quality measurements with respect to the RS, and switch to a new CC based on the signal quality measurements.

FIG. **1** illustrates a wireless communication system **100** that includes a UE **102** and an eNB **104**. The UE **102** is an electronic device that may be used for voice and/or data communication over a wireless communication network, such as a cellular network. The UE **102** may be a cellular phone, a smart phone, a personal digital assistant (PDA), a card in a laptop or personal computer, etc. The eNB **104** facilitates wireless communication between the UE **102** and a network. The eNB **104** is a fixed station that contains radio frequency transmitters and receivers that are used to communicate with UEs, which may move freely around the eNB **104**. Signals that are transmitted from the UE **102** to the eNB **104** are referred to as uplink signals, and signals that are transmitted from the eNB **104** to the UE **102** are referred to as downlink signals.

The UE **102** and the eNB **104** may be configured to operate in accordance with an LTE-Advanced standard. The total amount of bandwidth that is allocated to the eNB **104** may be partitioned into separate CCs **110**. Wireless electronic communication may occur between the UE **102** and the eNB **104** via one of the available CCs **110**. Other items shown in FIG. **1** will be discussed below in connection with the method shown in FIG. **2**.

FIG. **2** illustrates a method **200** for CC selection in a wireless communication system **100**. The method **200** may be implemented when the UE **102** is in idle mode. A UE **102** may receive **202** a reference signal (RS) **108** from an eNB **104** via a particular CC **110**, which may be referred to herein as the "current" CC **110**. The UE **102** may obtain **204** signal quality measurements **106** with respect to the RS **108**. The signal quality measurements **106** may provide information about the signal quality of the current CC **110**. The signal quality measurements **106** may include received power **116** and received interference **118**. The UE **102** may switch **206** to a new CC **110** based on the signal quality measurements **106**. For

example, if the signal quality measurements **106** indicate that the received power **116** of the current CC **110** is acceptable, but the interference **118** of the current CC **110** is too high, and there is at least one other CC **110** available that may provide adequate power **116** but less interference **118**, then the UE **102** may switch **206** to the other CC **110**. In this context, "switch" means that the UE **102** re-tunes and monitors another CC **110** of the current eNB **104**.

FIG. **3** illustrates a wireless communication system **300** that includes a UE **302**, an eNB **304***a*, and one or more other eNBs **304***b*. The UE **302** and the eNB **304***a* may be configured to operate in accordance with an LTE-Advanced standard, and wireless electronic communication may occur between the UE **302** and the eNB **304***a* via one of multiple CCs **310**. Other items shown in FIG. **3** will be discussed below in connection with the methods shown in FIGS. **4-16**.

FIG. **4** illustrates a method **400** for CC selection in a wireless communication system **300**. The method **400** may be implemented when the UE **302** is in idle mode. A UE **302** may receive **402** a reference signal (RS) **312** from an eNB **304***a* via a particular CC **310**, which may be referred to herein as the "current" CC **310**. The UE **302** may obtain **404** signal quality measurements **306** with respect to the RS **312**. The signal quality measurements **306** may include received power **316** and received interference **318** with respect to the RS **312**.

A measure of interference in an LTE-Advanced system may originate from one of the following sources: RSSI (Reference Signal Strength Indicator), RSRQ (Reference Signal Received Quality), CQU (Channel Quality Indicator), or a custom RS. An additional load based metric might be signaled by the network to the UE **302** in order to improve the RSRQ estimates (i.e., load==amount of data traffic carried by the eNB **304***a*).

The UE **302** may determine **406** whether the received power **316** is less than a defined threshold **320**, which may be referred to herein as a power threshold **320**. If the received power **316** is not less than the power threshold **320**, then the UE **302** may determine **408** whether the received interference **318** exceeds a threshold **322**, which may be referred to herein as an interference threshold **322**. If the received interference **318** does not exceed the interference threshold **322**, then the method **400** may end.

If the received interference **318** exceeds the interference threshold **322**, then the UE **302** may determine **410** whether there is at least one other CC **310** available via which the UE **302** may communicate with the eNB **304***a*. If not, then the method **300** may end. However, if there is at least one other available CC **310**, then the UE **302** may select **412** a CC **310** to switch to, and the UE **302** may switch **414** to the selected CC **310**.

If the UE **302** determines **406** that the received power **316** is less than the power threshold **320**, then the UE **302** may determine **415** whether there are any CCs **310** on this eNB **304***a* that have an RS power that is greater than the power threshold **320**. If so, then the method **400** may proceed to decision block **408** and continue in the manner described above. If the UE **302** determines **415** that there are not any CCs **310** on this eNB **304***a* that have an RS power that is greater than the power threshold **320**, then the UE **302** may switch **416** to another eNB **304***b*.

FIG. **5** illustrates another method **500** for CC selection in a wireless communication system **300**. The method **500** may be implemented when the UE **302** is in idle mode. A UE **302** may receive **502** a reference signal (RS) **312** from an eNB **304***a* via a particular CC **310**, which may be referred to herein as the "current" CC **310**. The UE **302** may obtain **504** the received power **316** with respect to the RS **312**. The UE **302** may determine **506** whether the received power **316** is less than the power threshold **320**.

If the received power **316** is not less than the power threshold **320**, then the UE **302** may attempt **508** to decode data packets **314** received from the eNB **304***a*. The data packets **314** may be broadcasted by the eNB **304***a* via the PDCCH, PBCH, etc. If the data packets **314** are decodable, then the method **500** may end. If the data packets **314** are not decodable, then the UE **302** may determine **510** whether there is at least one other CC **310** available via which the UE **302** may communicate with the eNB **304***a*. If not, then the method **500** may end. However, if there is at least one other available CC **310**, then the UE **302** may select **512** a CC **310** to switch to, and the UE **302** may switch **514** to the selected CC **310**.

If the UE **302** determines **506** that the received power **316** is less than the power threshold **320**, then the UE **302** may determine **515** whether there are any CCs **310** on this eNB **304***a* that have an RS power that is greater than the power threshold **320**. If so, then the method **500** may proceed to decision block **508**, and continue in the manner described above. If the UE **302** determines **515** that there are not any CCs **310** on this eNB **304***a* that have an RS power that is greater than the power threshold **320**, then the UE **302** may switch **516** to another eNB **304***b*.

The methods shown in FIGS. **4** and **5** both involve selecting **412**, **512** a CC **310** for the UE **302** to switch to. There are many ways that this may be accomplished.

FIG. **6** illustrates a method **600** for selecting **412**, **512** a CC **310** for the UE **302** to switch to. The UE **302** may determine **602** whether there are any CCs **310** in increasing frequency (relative to the current CC **310**) that are available. If so, then the UE **302** may select **604** the next available CC **310** in increasing frequency. Otherwise, the UE **302** may select **606** the lowest frequency CC **310** (other than the current CC **310**) that is available.

FIG. **7** illustrates another method **700** for selecting **412**, **512** a CC **310** for the UE **302** to switch to. The UE **302** may determine **702** whether there are any CCs **310** in decreasing frequency (relative to the current CC **310**) that are available. If so, then the UE **302** may select **704** the next available CC **310** in decreasing frequency. Otherwise, the UE **302** may select **706** the highest frequency CC **310** (other than the current CC **310**) that is available.

FIG. **8** illustrates another method **800** for selecting **412**, **512** a CC **310** for the UE **302** to switch to. The UE **302** may associate **802** each of N available CCs **310** with a number between 1 and N, so that each available CC **310** is associated with a different number. The UE **302** may randomly select **804** a number between 1 and N. The UE **302** may then select **806** the CC **310** that corresponds to the randomly selected number. If the result of the random number selection maps to the currently used CC **310**, then the random number selection process is repeated until a number is selected that does not map to the currently used CC **310**.

FIG. **9** illustrates another method **900** for selecting **412**, **512** a CC **310** for the UE **302** to switch to. The UE **302** may receive **902** a sequence **324** of CCs **310** from the eNB **304***a*. The sequence **324** may specify which CC **310** is to be selected after the current CC **310**. The UE **302** may select **904** a CC **310** to switch to based on the sequence **324**.

FIG. **10** illustrates another method **1000** for selecting **412**, **512** a CC **310** for the UE **302** to switch to. The UE **302** may request **1002** that the eNB **304***a* inform the UE **302** of which CC **310** it should switch to. In response, the UE **302** may receive **1004** from the eNB **304***a* an indication of the CC **310** that the UE **302** should switch to.

FIG. **11** illustrates another method **1100** for selecting **412**, **512** a CC **310** for the UE **302** to switch to. The UE **302** may derive **1102** a sequence **324** from an identifier **326**. The identifier **326** may be a cell identifier, a UE identifier, etc. The UE **302** may select **1104** the CC **310** that the UE **302** switches to based on the derived sequence **324**.

As discussed above in connection with the methods shown in FIGS. **4** and **5**, under some circumstances the UE **302** may switch **414**, **514** to another CC **310**. FIG. **12** illustrates a method **1200** that may be performed by the UE **302** in connection with attempting to switch **414**, **514** to another CC **310**.

In the depicted method **1200**, the UE **302** may attempt **1202** to switch to another CC **310**. If the UE **302** determines **1204** that it has successfully switched to another CC **310**, then the UE **302** may reset **1206** a variable **328** (which may be referred to herein as an unsuccessful attempts variable **328**) to zero. The UE **302** may also signal **1216** the eNB **304***a* to inform the eNB **304***a* that the UE **302** has successfully switched to another CC **310**. However, if the UE **302** determines **1204** that it has not successfully switched to another CC **310**, then the UE **302** may increment **1208** the unsuccessful attempts variable **328**.

The UE **302** may also determine **1210** whether a defined time period **330** has elapsed. If the time period **330** has elapsed, then the method **1200** may end. However, if the time period **330** has not elapsed, then the UE **302** may determine **1212** whether the unsuccessful attempts variable **328** equals a defined value, which may be referred to herein as "m". (The time period **330** and the value of m are configurable and may be signaled to the UE **302** by the eNB **304***a*.) If it is determined **1212** that the unsuccessful attempts variable **328** does not equal m, then the method **1200** may end. However, if it is determined **1212** that the unsuccessful attempts variable **328** equals m, then the UE **302** may switch **1214** to another eNB **304***b*.

FIG. **13** illustrates another method **1300** that may be performed by the UE **302** in connection with attempting to switch **414**, **514** to another CC **310**. In the depicted method **1300**, the UE **302** may attempt **1302** to switch to another CC **310**. If the UE **302** determines **1304** that it has successfully switched to another CC **310**, then the UE **302** may reset **1306** the unsuccessful attempts variable **328** to zero, and signal **1308** the eNB **304***a* to inform the eNB **304***a* that the UE **302** has successfully switched to another CC **310**.

However, if the UE **302** determines **1304** that it has not successfully switched to another CC **310**, then the UE **302** may increment **1310** the unsuccessful attempts variable **328**. The UE **302** may then determine **1312** whether the unsuccessful attempts variable **328** equals a defined value (m). If it is determined **1312** that the unsuccessful attempts variable **328** does not equal m, then the method **1300** may end. However, if it is determined **1312** that the unsuccessful attempts variable **328** equals m, then the UE **302** may switch **1314** to another eNB **304***b*.

FIG. **14** illustrates another method **1400** for selecting **412**, **512** a CC **310** for the UE **302** to switch to. A UE **302** may obtain **1402** signal quality measurements **332** with respect to other available CCs **310**. The signal quality measurements **332** may include received power **334** and received interference **336**. The UE **302** may apply **1404** weighted values **338** to results of the signal quality measurements **332**. The weighted values **338** may have been supplied by the eNB **304***a*, such that each weighted value **338** is associated with a specific CC's received power **334** or received interference **336** value. The UE **302** may also apply **1406** selection criteria **340** to the weighted results. The selection criteria **340** for the best CC **310** could be the best received power **334**, the lowest received interference **336**, or a combination thereof.

FIG. **15** illustrates another method **1500** for selecting **412**, **512** a CC **310** for the UE **302** to switch to. The UE **302** may select **1502** available CCs **310** for which signal quality measurements **332** will be obtained based on an identifier **326**. The identifier **326** may be cell-specific, UE-specific, etc. The UE **302** may obtain **1504** signal quality measurements **332** with respect to the selected CCs **310**. The UE **302** may determine **1506** offsets **342** (e.g., Qoffsets) for the CCs **310**. The UE **302** may determine **1508** that an offset **342** for a particular CC **310** has been adjusted by the eNB **304***a* based on offsets **342** for adjacent CCs **310**. The UE **302** may determine **1510** that an offset **342** for a particular CC **310** has been adjusted by the eNB **304***a* based on received power **334** of the CC **310**. The UE **302** may determine **1512** that an offset **342** for a particular CC **310** has been adjusted by the eNB **304***a* based on received interference **336** of other CCs **310**. Under some circumstances, an offset **342** between CCs **310** may be used (e.g., Qoffsetcomponent). An offset **342** between CCs **310** may be a modification of the current Qoffsetfrequency defined in the specifications or a new offset defined just for CCs **310**. The UE **302** may generate **1514** rankings **344** for the CCs **310** based on the signal quality measurements **332** and the offsets **342**.

In the methods shown in FIGS. **4** and **5**, the UE **302** may switch **416**, **516** to another eNB **304***b* under some circumstances. FIG. **16** illustrates a method **1600** for selecting the eNB **304***b* that the UE **302** should switch to. The method **1600** may be performed if the current eNB **304***a* is configured for operation in accordance with LTE-Advanced or LTE.

The UE **302** may obtain **1602** signal quality measurements **346** with respect to other eNBs **304***b*. The signal quality measurements **346** may include received power **348** and received interference **350**. The UE **302** may apply **1604** an offset **352** (e.g., Qoffset) to the received power **348** for each eNB **304***b* whose received interference **350** exceeds the interference threshold **322**. The magnitude of the offset **352** may be related to the level of interference **350**. The UE **302** may generate **1606** rankings **354** for the other eNBs **304***b* based on the received power **348** and the offsets **352**.

FIG. **17** illustrates a method **1700** that may be implemented in a UE in order to determine reselection to another eNB or reconfiguration to another CC. In the method **1700**, a UE may determine **1702** whether the received power of a reference signal is less than a defined power threshold. If the received power of the reference signal is not less than the defined power threshold, then the UE may determine **1704** whether the interference of the reference signal is greater than a defined interference threshold. If it is, then the UE may determine **1708** whether it is currently camped on an LTE-Advanced type eNB. If it is, then the UE may determine **1710** whether there are other available CCs to camp on. If there are, then the UE may reconfigure **1714** to another CC on the currently serving eNB. If the UE determines **1708** that it is not camped on an LTE-Advanced type eNB, or if the UE determines **1710** that there are not any other CCs to camp on, then the UE may reselect **1712** to another eNB.

If the UE determines **1704** that the interference of the reference signal is not greater than the defined interference threshold, then the UE may determine **1706** whether it is able to successfully decode data received from the currently serving eNB. If it can, then the method may end. If it cannot, then the UE may determine **1708** whether the UE is camped on an LTE-Advanced type eNB, and then continue in the manner described above.

If the UE determines **1702** that the received power of the reference signal is less than the defined power threshold, then the UE may determine **1715** whether there are any CCs on this eNB that have an RS power that is greater than the power threshold. If so, then the method **1700** may proceed to decision block **1704** and continue in the manner described above. If the UE determines **1715** that there are not any CCs on this eNB that have an RS power that is greater than the power threshold, then the UE may reselect **1712** to another eNB.

FIG. **18** illustrates a method **1800** that may be implemented in a UE in order to determine if reselection to another eNB is necessary after a failed reconfiguration. In the method **1800**, a UE may determine **1802** whether a reconfiguration has failed. If not, the method **1800** may end.

If the UE determines **1802** that a reconfiguration has failed, then the UE may determine **1804** whether there are other available CCs to camp on. If there are, then the UE may determine **1806** whether a timer has expired. If it has not yet expired, then the UE may determine **1808** whether the number of unsuccessful reselections within a defined time period (which is indicated by the timer) is equal to a defined value ("m"). If it is not, then the UE may attempt to reconfigure **1810** to another CC on the currently serving eNB. If the reconfiguration attempt fails, a variable that indicates the number of unsuccessful reselections within the defined time period may then be incremented **1812**.

If the UE determines **1806** that the timer has expired, then the UE may restart **1814** the timer and reset **1816** the variable that indicates the number of unsuccessful reselections within the defined time period to zero. The UE may then reconfigure **1810** to another CC on the currently serving eNB, and proceed in the manner described above.

If the UE determines **1804** that there are not any other available CCs to camp on, then the UE may reselect **1818** to another eNB, restart **1820** the timer, and reset **1822** the variable that indicates the number of unsuccessful reselections within the defined time period to zero.

If the UE determines **1808** that the number of unsuccessful reselections within the defined time period is equal to m, then the UE may reselect **1818** to another eNB and proceed in the manner described above.

FIG. **19** illustrates another method **1900** that may be implemented in a UE in order to determine if reselection to another eNB is necessary after a failed reconfiguration. In the method **1900**, a UE may determine **1902** whether a reconfiguration has failed. If not, a variable that indicates the number of sequential unsuccessful reselections may be reset **1914** to zero, and the method **1900** may end.

If the UE determines **1902** that a reconfiguration has failed, the UE may then determine **1904** whether there are other available CCs to camp on. If there are, then the UE may determine **1906** whether a variable that indicates the number of sequential unsuccessful reselections is equal to a defined value ("m"). If not, the UE may attempt to reconfigure **1908** to another CC on the currently serving eNB. If the reconfiguration attempt fails, then the UE may increment **1910** the variable that indicates the number of sequential unsuccessful reselections.

If the UE determines **1904** that there are not any other available CCs to camp on, then the UE may reselect **1912** to another eNB. Also, if the UE determines **1906** that the number of sequential unsuccessful reselections is equal to m, then the UE may reselect **1912** to another eNB. The UE may then reset **1914** the variable that indicates the number of sequential unsuccessful reselections to zero.

Above, systems and methods were described that relate to CC selection for a UE that is in idle mode. Next, systems and methods will be described that relate to CC selection for a UE that is in connected mode.

A desired functionality of an LTE-Advanced system is to be able to "load balance" such that a eNB can command a UE transmitting and receiving on CCx to change its CC allocation to CCy. To implement such a change effectively, the eNB should know the channel conditions between the eNB and the UE (i.e., both the uplink and downlink RF channel conditions). The LTE system uses sounding reference signal (SRS) symbols transmitted by the UE or perhaps other measurement signals at scheduled time/frequency locations to measure the UL channel condition. The system uses received signal strength indication (RSSI), Channel Quality Indicators (CQI) and other metrics based on quality of service (QoS) or grade of service (GoS) as measured by the UE, to determine the downlink channel conditions. Measurements taken by the UE are subsequently transmitted to the eNB, which is measuring uplink channel conditions.

The LTE eUTRAN (Evolved Universal Terrestrial Radio Access Network) measurement procedure does not support a mechanism whereby the eNB can provide the following information and commands to the UE:

1. A UL resource grant indicating time and frequency resource(s) on other CCs whereby the UE is to transmit a SRS or other medium measuring signal.

2. A DL resource grant indicating time and frequency resource(s) on other CCs whereby the UE is to measure the reference signals (RS) and other QoS metrics.

3. A UL resource grant indicating time and frequency resource(s) whereby the UE is to transmit the results of the RSSI, CQI QoS, and/or GoS measurements back to the eNB.

Additionally, the eNB does not currently take into account the results of the above UL and DL measurements when making the determination of which CC the UE should be commanded to change to.

The present disclosure provides means whereby the LTE eUTRAN measurement procedure is extended to include the necessary scheduling and resource grants such that the eNB can command the UE to transmit the SRS in UL channels, measure the RS in DL channels, and transmit the measurement results to the eNB. The above extensions will provide the eNB with the means to determine the best CC to command the UE to change to.

A method for component carrier (CC) selection for a user equipment (UE) that is in connected mode is disclosed. An evolved Node B (eNB) obtains uplink channel condition information corresponding to uplink CCs and downlink channel condition information corresponding to downlink CCs. The eNB selects a CC pair for the UE to use based on the uplink channel condition information and the downlink channel condition information.

In order to obtain the uplink channel condition information, the eNB may send a configuration message to the UE such that the UE can transmit a sounding reference signal (SRS) on other uplink CCs. The eNB may also receive and measure the SRS on the uplink CCs on which the UE was directed to transmit. The eNB may also determine uplink CC channel condition values based on uplink CC SRS measurements. The eNB may also generate a ranking order for each uplink CC. The ranking order may be derived from the uplink CC channel condition values by applying weighted factors.

In order to obtain the downlink channel condition information, the eNB may send a configuration message to the UE such that the UE can take measurement on a reference signal (RS) on other downlink CCs. The eNB may grant to the UE

scheduling resources whereby the UE can transmit the RS measurement taken on the other downlink CCs. The eNB may determine downlink CC channel condition values based on downlink CC RS measurements received from the UE. The eNB may generate a ranking order for each downlink CC. The ranking order may be derived from the downlink CC channel condition values by applying weighted factors.

The eNB may initiate the CC selection for the UE when the eNB detects that the UE has transitioned from idle mode to the connected mode. Alternatively, the eNB may be a target eNB that initiates the CC selection for the UE when the eNB detects that the UE has completed a handoff from a source eNB. Alternatively, the eNB may initiate the CC selection for the UE when the eNB detects that the UE has initiated a Target Area (TA) update.

An evolved Node B (eNB) that is configured for component carrier (CC) selection for a user equipment (UE) that is in connected mode is also disclosed. The eNB includes a processor, memory in electronic communication with the processor, and instructions stored in the memory. The instructions are executable to obtain uplink channel condition information corresponding to uplink CCs and to obtain downlink channel condition information corresponding to downlink CCs. The instructions are also executable to select a CC pair for the UE to use based on the uplink channel condition information and the downlink channel condition information.

A method for component carrier (CC) selection for a user equipment (UE) that is in connected mode is also disclosed. A source evolved Node B (eNB) initiates a determination of a target CC of a target eNB for the UE to use following handoff of the UE from the source eNB to the target eNB. The source eNB command the UE to make measurements on the target eNB. The source eNB and the target eNB communicate about time/frequency resources that the UE will use to make the measurements.

The source eNB may initiate the determination of the target CC in response to the source eNB detecting that the UE should prepare for the handoff from the source eNB to the target eNB. Alternatively, the source eNB may initiate the determination of the target CC in response to the source eNB preparing the UE for the handoff from the source eNB to the target eNB.

The UE may send the results of the measurements to the target eNB. The target eNB may analyze the results and determine the target CC. The target eNB may inform the UE of the target CC.

The UE may send the results of the measurements to the source eNB. The source eNB may forward the results to the target eNB. The target eNB may analyze the results and determine the target CC. The target eNB may inform the source eNB of the target CC. The source eNB may inform the UE of the target CC.

FIG. **20** illustrates a wireless communication system **2000** that includes a UE **2002** and an eNB **2004**. The UE **2002** and the eNB **2004** may be configured to operate in accordance with an LTE-Advanced standard. The total amount of bandwidth that is allocated to the eNB **2004** may be partitioned into separate CCs **2010**, which may include uplink CCs **2010***a* and downlink CCs **2010***b*. Other items shown in FIG. **20** will be discussed below in connection with the method shown in FIG. **21**.

FIG. **21** illustrates a method **2100** for CC selection in a wireless communication system **2000**. The method **2100** may be implemented when the UE **2002** is in connected mode. The UE **2002** may obtain **2102** uplink channel condition information **2056** corresponding to the uplink CCs **2010***a*. The UE **2002** may also obtain **2104** downlink channel condition information **2058** corresponding to the downlink CCs **2010***b*. The UE **2002** may select **2106** a CC pair (e.g., an uplink CC **2010***a* and a corresponding downlink CC **2010***b*) for the UE **2002** to use based on the uplink channel condition information **2056** and the downlink channel condition information **2058**.

FIG. **22** illustrates another wireless communication system **2200** that includes a UE **2202** and an eNB **2204**. The UE **2202** and the eNB **2204** may be configured to operate in accordance with an LTE-Advanced standard. The total amount of bandwidth that is allocated to the eNB **2204** may be partitioned into separate CCs **2210**, which may include uplink CCs **2210***a* and downlink CCs **2210***b*. Other items shown in FIG. **22** will be discussed below in connection with the method shown in FIG. **23**.

FIG. **23** illustrates a method **2300** for CC selection in a wireless communication system **2200**. The method **2300** may be implemented in the eNB **2204** when the UE **2202** is in connected mode.

In the depicted method **2300**, the eNB **2204** may send **2302** a configuration message **2276** to the UE **2202** such that the UE **2202** can transmit a sounding reference signal (SRS) **2260** on other uplink CCs **2210***a*. The eNB **2204** may receive and measure **2304** the SRS **2260** on the uplink CCs **2210***a* on which the UE **2202** was directed to transmit.

The eNB **2204** may send **2306** a configuration message **2276** to the UE **2202** such that the UE **2202** can take measurement on a reference signal (RS) **2212** on other downlink CCs **2210***b*. The eNB **2204** may grant **2308** to the UE **2202** scheduling resources whereby the UE **2202** can transmit the RS measurements **2264** taken on the other downlink CCs **2210***b*.

The eNB **2204** may determine **2310** uplink CC channel condition values **2266** based on uplink CC SRS measurements **2262**. The eNB **2204** may generate **2312** a ranking order **2272** for each uplink CC **2210***a*. The ranking order **2272** may be derived from the uplink CC channel condition values **2266** by applying weighted factors **2270**. Examples of weighted factors **2270** include loading, sectorization, UE speed, UE location, time of day, phase of the moon, etc.

The eNB **2204** may determine **2314** downlink CC channel condition values **2268** based on downlink CC RS measurements **2264** received from the UE **2202**. The eNB **2204** may generate **2316** a ranking order **2274** for each downlink CC **2210***b*. The ranking order **2274** may be derived from the downlink CC channel condition values **2268** by applying weighted factors **2270**.

The method **2300** may be performed by an eNB **2204** in response to the eNB **2204** detecting that an LTE-Advanced UE **2202** has transitioned from idle mode to connected mode. Alternatively, the method **2300** may be performed by an eNB **2204** in response to the eNB **2204** detecting that an LTE-Advanced UE **2202** has initiated a Target Area (TA) update. A TA is a logical grouping of eNBs. A TA update is a procedure whereby the UE **2202** (when it is idle mode) notifies the EUTRA that it has moved (i.e., reselected) from an eNB that is part of TA[**1**] to an eNB that is part of TA[**2**]. Alternatively, the method **2300** may be performed by a target eNB **2204** in response to the target eNB **2204** detecting that an LTE-Advanced UE **2202** has completed a handoff from a source eNB.

FIG. **24** illustrates a wireless communication system **2400** that includes a UE **2402**, a source eNB **2404***a* and a target eNB **2204***b*. The UE **2402** and the eNBs **2404***a*, **2404***b* may be configured to operate in accordance with an LTE-Advanced standard. The total amount of bandwidth that is allocated to the eNBs **2404***a*, **2404***b* may be partitioned into separate CCs

2410*a*, 2410*b*. Other items shown in FIG. **24** will be discussed below in connection with the methods shown in FIGS. **25** and **26**.

FIG. **25** illustrates a method **2500** for CC selection in a wireless communication system **2400**. The method **2500** may be implemented when the UE **2402** is in connected mode. The source eNB **2404***a* may initiate the method **2500** as part of the source eNB **2404***a* detecting that the UE **2402** should prepare for a handoff from the source eNB **2404***a* to the target eNB **2404***b*.

In the depicted method **2500**, the source eNB **2404***a* may initiate **2502** a determination of a target CC **2478** of the target eNB **2404***b* for the UE **2402** to use following handoff of the UE **2402** from the source eNB **2404***a* to the target eNB **2404***b*. The source eNB **2404***a* may command **2504** the UE **2402** to make measurements on the target eNB **2404***b*. The source eNB **2404***a* and the target eNB **2404***b* may communicate **2506** about time/frequency resources that the UE **2402** will use to make the measurements. The UE **2402** may send **2508** the results **2480** of the measurements to the target eNB **2404***b*. The target eNB **2404***b* may analyze the results **2480** and determine **2510** the target CC **2478**. The target eNB **2404***b* may inform **2512** the UE **2402** of the target CC **2478**.

FIG. **26** illustrates another method **2600** for CC selection in a wireless communication system **2400**. The method **2600** may be implemented when the UE **2402** is in connected mode. The source eNB **2404***a* may initiate the method **2600** as part of the source eNB **2404***a* preparing the UE **2402** for a handoff from the source eNB **2404***a* to the target eNB **2404***b*.

In the depicted method **2600**, the source eNB **2404***a* may initiate **2602** a determination of a target CC **2478** of the target eNB **2404***b* for the UE **2402** to use following handoff of the UE **2402** from the source eNB **2404***a* to the target eNB **2404***b*. The source eNB **2404***a* may command **2604** the UE **2402** to make measurements on the target eNB **2404***b*. The source eNB **2404***a* and the target eNB **2404***b* may communicate **2606** about time/frequency resources that the UE **2402** will use to make the measurements. The UE **2402** may send **2608** the results **2480** of the measurements to the source eNB **2404***a*. The source eNB **2404***a* may forward **2610** the results **2480** to the target eNB **2404***b*. The target eNB **2404***b* may analyze the results **2480** and determine **2612** the target CC **2478**. The target eNB **2404***b* may inform **2614** the source eNB **2404***a* of the target CC **2478**. The source eNB **2404***a* may inform **2616** the UE **2402** of the target CC **2478**.

FIG. **27** illustrates a RACH procedure, where commands to measure other CCs before reconfiguration are not provided. A UE **2702** sends a first message **2706** to an eNB **2704**. The first message **2706** is sent via the PRACH (Physical Random Access Channel). The first message **2706** includes a 6-bit random ID (also known as the "preamble"). The first message **2706** is initiated on the physical layer.

The eNB **2704** then sends a second message **2708** to the UE **2702**. The second message **2708** is sent via the PDCCH[RA-RNTI] (PDCCH stands for the Physical Downlink Control Channel, and RNTI stands for Radio Network Temporary Identifier), which points to the PDSCH. The PDSCH (Physical Downlink Shared Channel) contains the same 6-bit random ID as in the first message **2706**, an uplink grant, a timing advance command, and a T-CRNTI (Temporary Cell RNTI). The second message **2708** is initiated on the MAC (Medium Access Control) layer.

The UE **2702** then sends a third message **2710** to the eNB **2704**. The third message **2710** is sent via the PUSCH[UL-SCH[CCCH]] (PUSCH stands for Physical Uplink Shared Channel, UL-SCH stands for Uplink Shared Channel, and CCH stands for Common Control Channel). The CCCH includes a 32-bit S-TMSI (S-Temporary Mobile Subscriber Identity) or random number, and an RRC (Radio Resource Control) connection request. The third message **2710** is initiated on the RRC.

The eNB **2704** then sends a fourth message **2712** to the UE **2702**. The fourth message **2712** is sent via the PDCCH[T-CRNTI], which points to the PDSCH. The PDSCH contains the RRC connection setup. The fourth message **2712** is initiated on the RRC.

The UE **2702** then sends a fifth message **2714** to the eNB **2704**. The fifth message **2714** indicates the UE's capability, i.e., it identifies features that are supported by the UE **2702**. The eNB **2704** then sends a sixth message **2716** to the UE **2702**. The sixth message **2716** includes an RRC connection reconfiguration message, which requests that the UE **2702** move to a new CC.

FIG. **28** illustrates a RACH procedure, where commands to measure other CCs before reconfiguration are provided. A UE **2802** sends a first message **2806** to an eNB **2804**. The first message **2806** is sent via the PRACH. The first message **2806** includes a 6-bit random ID (also known as the "preamble"). The first message **2806** is initiated on the physical layer.

The eNB **2804** then sends a second message **2808** to the UE **2802**. The second message **2808** is sent via the PDCCH[RA-RNTI], which points to the PDSCH. The PDSCH includes the same 6-bit random ID as in the first message **2806**, an uplink grant, a timing advance command, and a T-CRNTI. The second message **2808** is initiated on the MAC layer.

The UE **2802** then sends a third message **2810** to the eNB **2804**. The third message **2810** is sent via the PUSCH[UL-SCH[CCCH]]. The CCCH contains a 32-bit S-TMSI or random number and an RRC connection request. The third message **2810** is initiated on the RRC.

The eNB **2804** then sends a fourth message **2812** to the UE **2802**. The fourth message **2812** is sent via the PDCCH[T-CRNTI], which points to the PDSCH. The PDSCH contains an RRC connection setup. The fourth message **2812** is initiated on the RRC.

The UE **2802** then sends a fifth message **2814** to the eNB **2804**. The fifth message **2814** indicates the UE's capability, i.e., it identifies features that are supported by the UE **2802**. The eNB **2804** then sends a sixth message **2816** to the UE **2802**. The sixth message **2816** indicates time/frequency resources, including the configuration for transmission of SRS in uplink CCs, the configuration for reception of RS in downlink CCs, and the grant for reporting the measurement results. The UE **2802** and the eNB **2804** then exchange QOS SRS measurements **2818**. The UE **2802** then sends a message **2820** to the eNB **2804** reporting the results of RS measurements from other CCs. The eNB **2804** sends an RRC connection reconfiguration message **2822** to the UE **2802**, requesting that the UE **2802** move to a new CC.

FIG. **29** illustrates a method **2900** that may be performed by an eNB for determining the best CC band pair for a UE. In the method **2900**, the eNB may determine **2902** whether the UE is of type LTE-Advanced. If not, the method **2900** may end. If the UE is of type LTE-Advanced, then the eNB may define **2904** "Y**1** . . . Yn" as the set of UL CCs that the eNB considers available for the UE, and "X**1** . . . Xm" as the set of DL CCs that the eNB considers available for the UE.

The eNB may create **2906** a SoundingRS-UL-Config IE that identifies that time and frequency resources for SRS transmission in the Y**1** . . . Yn UL CCs. The eNB may create **2908** a Measurement Configuration IE that identifies the time and frequency resources and measurement gaps for RS reception in the X**1** . . . Xm DL CCs. The eNB may send **2910**, via an RRCConnectionReconfiguration message, the Measure-

ment Configuration IE and the SoundingRS-UL-Config IE. The eNB may send **2912** an UL grant such that the UE can report the RS measurements on the X1 . . . Xm DL CCs.

When the eNB determines **2914** that it is ready to measure SRS transmissions, then it may measure **2916** the SRS transmitted by the UE on the designated time and frequency resources of the Y1 . . . Yn UL CCs. When the eNB determines **2918** that it is ready to receive RS measurements from the UE, then the eNB may receive **2920** from the UE on the scheduled UL grant the X1 . . . Xm DL CC RS measurement results as defined by the SoundingRS-UL-Config IE.

When the eNB determines **2922** that the SRS and RS measurements have been obtained, then the eNB may analyze **2924** the Y1 . . . Yn CC UL SRS measurements to determine the channel condition of each CC. The eNB may also analyze **2926** the X1 . . . Xm CC UL RS measurements to determine the channel condition of each CC. The eNB may generate **2928** a ranking order of the Y1 . . . Yn UL CCs (i.e., taking into account factors such as loading, etc.). The eNB may generate **2930** a ranking order of the X1 . . . Xm DL CCs (i.e., taking into account factors such as loading, etc.). The eNB may analyze **2932** the UL CC ranking order and the DL CC ranking order to determine which (if any) of the UL and DL CC pairs is the most appropriate for the UE to re-select to. The eNB may send **2934**, via an RRCConnectionReconfiguration message, the MobilityControlInfo IE to command the UE to reselect to the most appropriate CC pair band.

FIG. **30** illustrates various components that may be utilized in a communication device **3002**. The communication device **3002** may be a UE or an eNB. The communication device **3002** includes a processor **3006** that controls operation of the communication device **3002**. The processor **3006** may also be referred to as a CPU. Memory **3008**, which may include both read-only memory (ROM), random access memory (RAM) or any type of device that may store information, provides instructions **3007***a* and data **3009***a* to the processor **3006**. A portion of the memory **3008** may also include non-volatile random access memory (NVRAM). Instructions **3007***b* and data **3009***b* may also reside in the processor **3006**. Instructions **3007***b* loaded into the processor **3006** may also include instructions **3007***a* from memory **3008** that were loaded for execution by the processor **3006**. The instructions **3007** may be executed by the processor **3006** to implement the methods disclosed herein.

The communication device **3002** may also include a housing that contains a transmitter **3010** and a receiver **3012** to allow transmission and reception of data. The transmitter **3010** and receiver **3012** may be combined into a transceiver **3020**. An antenna **3018** is attached to the housing and electrically coupled to the transceiver **3020**. Additional antennas may also be used.

The various components of the communication device **3002** are coupled together by a bus system **3026** which may include a power bus, a control signal bus, and a status signal bus, in addition to a data bus. However, for the sake of clarity, the various buses are illustrated in FIG. **30** as the bus system **3026**. The communication device **3002** may also include a digital signal processor (DSP) **3014** for use in processing signals. The communication device **3002** may also include a communications interface **3024** that provides user access to the functions of the communication device **3002**. The communication device **3002** illustrated in FIG. **30** is a functional block diagram rather than a listing of specific components.

The methods disclosed herein comprise one or more steps or actions for achieving the described method. The method steps and/or actions may be interchanged with one another without departing from the scope of the claims. In other words, unless a specific order of steps or actions is required for proper operation of the method that is being described, the order and/or use of specific steps and/or actions may be modified without departing from the scope of the claims.

It is to be understood that the claims are not limited to the precise configuration and components illustrated above. Various modifications, changes and variations may be made in the arrangement, operation and details of the systems, methods, and apparatus described herein without departing from the scope of the claims.

What is claimed is:

1. A method for a user equipment (UE) that is in connected mode, comprising:
- communicating with a source evolved Node B (eNB) using a plurality of component carriers;
- receiving a command to make measurements on a target eNB;
- measuring time/frequency resources; and
- sending results of the measurements on the time/frequency resources to the source eNB;
- wherein the source eNB initiates a determination of a target component carrier (CC) of a target eNB;
- wherein the source eNB forwards the results of the measurements on the time/frequency resources to the target eNB;
- wherein the source eNB and the target eNB communicate to determine time/frequency resources that the UE will use to make the measurements; and
- wherein the target CC is for the UE to use following handoff of the UE from the source eNB to the target eNB.

2. The method of claim **1**, wherein the source eNB initiates the determination of the target CC in response to the source eNB detecting that the UE should prepare for the handoff from the source eNB to the target eNB.

3. The method of claim **1**, wherein the source eNB initiates the determination of the target CC in response to the source eNB preparing the UE for the handoff from the source eNB to the target eNB.

4. The method of claim **1**, further comprising:
- the UE sending results of the measurements to the target eNB;
- the target eNB analyzing the results and determining the target CC; and
- the target eNB informing the UE of the target CC.

5. The method of claim **1**, further comprising:
- the target eNB analyzing the results and determining the target CC;
- the target eNB informing the source eNB of the target CC; and
- the source eNB informing the UE of the target CC.

6. A source evolved Node B (eNB) comprising:
- a processor;
- memory in electronic communication with the processor;
- instructions stored in the memory, the instructions being executable to:
- communicate with a user equipment (UE) using a plurality of component carrier (CC);
- initiate a determination of a target CC of a target evolved Node B(eNB), wherein the target CC is for the UE to use following handoff of the UE from the source eNB to the target eNB;
- command the UE to make measurements on the target eNB;
- communicate with the target eNB to determine time/frequency resources that the UE will use to make the measurements;

receive results of the measurements on the time/frequency resources from the UE; and

forward the results of the measurements on the time/frequency resources to the target eNB.

7. A non-transitory processor-readable medium comprising executable instructions, the instructions being executable to:

communicate with a source evolved Node B (eNB) using a plurality of component carriers;

receive a commands to make measurements on a target eNB;

measure time/frequency resources;

send results of the measurements on the time/frequency resources to the source eNB;

wherein the source eNB initiates a determination of a target component carrier (CC) of a target eNB;

wherein the source eNB forwards the results of the measurements on the time/frequency resources to the target eNB;

wherein the source eNB and that target eNB communicate to determine time/frequency resources that the UE will use to make the measurements; and

wherein the target CC is for the UE to use following handoff of the UE from the source eNB to the target eNB.

* * * * *